Mathematicall MAGICK OR, THE VVONDERS

That may be performed by *Mechanicall Geometry.*

In two Books.

CONCERNING

Mechanicall { POWERS. MOTIONS.

BEING ONE OF

The most easie, pleasant, usefull, (and yet most neglected) part of *MATHEMATICKS.*

Not before treated of in this language.

By *I. W. M. A.*

Τέχνη κρατοῦμεν ὧν φύσει νικώμεθα.

LONDON,
Printed by *M. F.* for *Sa: Gellibrand* at the brasen Serpent in *Pauls* Church-yard. 1648.

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Mathematical

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By I. Wi. M.

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Printed by M. C. for Ioh. Wa[illegible] at the
Signe of the Sun in Paul's Church-yard. 1648

TO HIS HIGHNESSE, The Prince Elector Palatine.

May it please your Highnesse.

I should not thus have presented my diversions, where I owe my duty and humblenesse, but that where all is due, a man may not justly withhold any part.

This following Discourse was composed some years since at my spare houres in the University. The subject of it is termed Mathematicks which I did the rather at such times make choice of, aiming for the pleasure *of it, more proper for recreation, and for the* facility *more suitable to my abilities and leisure.*

I should not Sir, have been ambitious of any so Great (*I could not of any better*) *Patronage, had not my relation both engaged and emboldned me to this Dedication.*

They that know your Highnesse how great an encourager you are, and how able

a Judge in all kind of ingenuous arts and literature, must needs acknowledge your pressures and low condition, to be none of the least mischiefs (amongst those many other) under which the Common-wealth of learning does now suffer.

It would in many respects much conduce to the generall advancement of religion and learning, if the reformed Churches in whose cause and defence your family hath so deeply suffered, were but effectually mindfull of their engagements to it. And particularly, if these present unhappy differences of this Nation did not occasion too much forgetfulnesse of their former zeal and professions for the vindicating *of your family, and the* restoring *of your Highnesse; the hastning and accomplishment of which, together with the increase of all heavenly blessings upon your Highnesse, shall be the hearty dayly prayer of*

Your Highnesse

most humble and most devoted

servant and Chaplain,

JOHN WILKINS.

TO THE READER.

IT is related of *Heraclitus* that when his Scholars had found him in a tradesmans shop, whether they were ashamed to enter. He told them, *Quod neque tali loco dii desunt immortales*, that the gods were as well conversant in such places as in others; Intimating that a divine power and wisdome might be discerned even in those common arts, which are so much despited; And though the manuall exercise and practise of them be esteemed ignoble, yet the study of their generall causes and principles, cannot bee prejudiciall to any other (though the most sacred) profession.

It hath been my usuall custome in the course of my other studies, to propose divers Mathematicall or Philosophicall inquiries, for the recreation of my leisure howers, and as I could gather satisfaction to compose them into some form and method.

Some of these have been formerly publi-

shed, and I have now ventured forth this discourse; wherein besides the great *delight and pleasure* (which every rationall Reader must needs finde in such notions as carry with them their own evidence and demonstration) there is also much *real benefit* to be learned; particularly for such Gentlemen as employ their estates in those chargeable adventures of Drayning, Mines, Cole-pits, &c. who may from hence learn the chief grounds & nature of Engines, & thereby more easily avoid the delusions of any cheating Impostor: And also for such *common artificers*, as are well skilled in the *practise* of these arts, who may be much advantaged by the right understanding of their grounds and *Theory*.

Schot. Mathem. l. 2. *Ramus* hath observed, that the reason why *Germany* hath been so eminent for Mechanicall inventions, is because there have been publike Lectures of this kind instituted amongst them, and those not only in the learned languages, but also in the vulgar tongue, for the capacity of every unlettered ingenious Artificer.

Agrippa, De Vanit. Scient. ca. 49. This whole Discourse I call *Mathematicall Magick*, because the art of such Mechanicall inventions as are here chiefly insisted upon, hath been formerly so styled; and in allusion to vulgar opinion, which doth commonly attribute all such strange operations

unto

unto the power of Magick; For which reason the Ancients did name this art *Scientiarum*, or *Mirandorum Effectrix*.

The first book is called *Archimedes*; because he was the chiefest in discovering of Mechanicall *powers*.

The second is styled by the name of *Dedalus*, who is related to be one of the first & most famous amongst the Ancients for his skil in making *Automata*, or self-moving Engines: both these being two of the first Authors that did reduce Mathematicall principles unto Mechanicall experiments.

Other discourses of this kind, are for the most part large and voluminous, of great price and hardly gotten; and besides, there are not any of them (that I know of) in our vulgar tongue, for which these Mechanicall arts of all other are most proper. These inconveniences are here in some measure remedied, together with the addition (if I mistake not) of divers things very considerable, and not insisted upon by others.

The

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ARCHI-

ARCHIMEDES, OR, MECHANICALL Powers.

The first Book.

CHAP. I.

The excellency of these Arts. Why they were concealed by the Ancients. The Authours that have treated of them.

ALL those various studies about which the sons of men doe busie their endevours, may be generally compriſed under these three kinds:

- Divine.
- Naturall.
- Artificiall.

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To the first of these, is reducible, not onely the *speculation* of Theologicall truths, but also the *practise* of those virtues, which may advantage our minds, in the enquiry after their proper happinesse. And these arts alone may truly be styled liberall, *Quæ liberum faciunt hominem, quibus curæ virtus est*, (saith the divine Stoick) which set a man at liberty from his lusts and passions.

Sen. Ep. 88.

To the second may be referred all that knowledge, which concerns the frame of this great Universe, or the usuall course of providence in the government of these created things.

To the last doe belong all those inventions, whereby nature is any way quickned or advanced in her defects: These artificiall experiments being (as it were) but so many Essays, whereby men doe naturally attempt to restore themselves from the first generall curse inflicted upon their labours.

This following Discourse, does properly appertain to this latter kind.

Now

Now Art may be said, either to *imitate* nature, as in limming and pictures; or to *help* nature, as in medicine; or to *overcome*, and *advance* nature, as in these Mechanicall disciplines, which in this respect are by so much to be preferred before the other, by how much their end and power is more excellent. Nor are they therefore to bee esteemed lesse noble, because more practicall, since our best and most divine knowledge is intended for action, and those may justly be counted barren studies, which doe not conduce to practise as their proper end.

But so apt are we to contemn every thing which is common, that the ancient Philosophers esteemed it a great part of wisdome to conceale their learning from vulgar apprehension or use, thereby the better to maintain it, in its due honour and respect. And therefore did they generally vail all their Arts and Sciences, under such mysticall expressions, as might excite the peoples wonder

and reverence, fearing leſt a more eaſie and familiar diſcovery, might expoſe them to contempt. *Sic ipſa myſteria fabularum cuniculis operiuntur, ſummatibus tantum viris, ſapientia interprete, veri arcani conſciis; Contenti ſint reliqui, ad venerationem, figuris defendentibus à vilitate ſecretum*, ſaith a Platonick.

Macrobius Somn. Scip. l. 1. c. 2.

Hence was it, that the ancient Mathematicians did place all their learning in abſtracted ſpeculations, refuſing to debaſe the principles of that noble profeſſion unto Mechanicall experiments. Inſomuch, that thoſe very Authors amongſt them, who were moſt eminent for their inventions of this kind, and were willing by their own practiſe, to manifeſt unto the world, thoſe artificiall wonders, that might be wrought by theſe arts, as *Dædalus, Archytas, Archimedes, &c.* were notwithſtanding ſo much infected with this blind ſuperſtition, as not to leave any thing in writing, concerning the grounds and manner of theſe operations.

Quin-

Quintilian speaking to this purpose of *Archimedes*, saith thus. *Quamvis tantum tamque singularem Geometriæ usum, Archimedes, singularibus exemplis, & admirandis operibus ostenderit, propter quæ non humana sed divinæ scientiæ laudem sit adeptus, hæsit tamen in illa Platonis persuasione, nec ullam Mechanicam literam prodere voluit.* *Quint. l. 1. c. 10.*

By which means, posterity hath unhappily lost, not onely the benefit of those particular discoveries, but also the proficiency of those arts in generall. For when once the learned men did forbid the reducing of them to particular use, and vulgar experiment: others did thereupon refuse these studies themselves, as being but empty and useleſſe speculations. Whence it came to passe that the science of Geometry was so universally neglected, receiving little or no addition for many hundred years together. *Pet. Ram. Schol. Mathem. l. 1.*

Amongst these Ancients, the divine *Plato* is observed to be one of the greatest sticklers for this fond

opinion, ſeverely dehorting all his followers from proſtituting Mathematicall principles, unto common apprehenſion or practiſe. Like the envious Emperour *Tiberius*, who is reported to have killed an Artificer for making glaſſe malleable, fearing leſt thereby the price of metals might be debaſed. So he, in his ſuperſtition to Philoſophy, would rather chuſe to deprive the world of all thoſe uſefull and excellent inventions, which might be thence contrived, then to expoſe that profeſſion unto the contempt of the ignorant vulgar.

Plin. Nat. l. 36. c. 26.

But his Scholar *Ariſtotle*, (as in many other particulars, ſo likewiſe in this) did juſtly oppoſe him, and became himſelf one of the firſt Authours, that hath writ any methodicall Diſcourſe concerning theſe arts, chuſing rather a certain and generall benefit, before the hazzard that might accrue from the vain and groundleſſe diſ-reſpects of ſome ignorant perſons. Being ſo far from eſteeming Geometry diſhonoured by the applicati-

Ariſt. Quæſt. Mechan.

on

on of it to Mechanicall practiſes, that he rather thought it to be thereby adorned, as with curious variety, and to be exalted unto its naturall end. And whereas the Mathematicians of thoſe former ages, did poſſeſſe all their learning, as covetous men doe their wealth, only in thought and notion; the judicious *Ariſtotle*, like a wiſe Steward, did lay it out to particular uſe and improvement, rightly preferring the reality and ſubſtance of publike benefit, before the ſhadows of ſome retired ſpeculation, or vulgar opinion.

Since him there have been divers other Authors, who have been eminent for their writings of this nature. Such were *Hero Alexandrinus*, *Hero Mechanicus*, *Pappus Alexandrinus*, *Proclus Mathematicus*, *Vitruvius*, *Guidus Vbaldus*, *Henricus Monantholius*, *Galileus*, *Gnevara*, *Merſennus*, *Bettinus*, *&c.* Beſides many others, that have treated largely of ſeverall engines, as *Auguſtine Ramelli*, *Vittorio Zoncha*, *Jacobus Beſſonius*, *Vegetius*, *Lipſius*.

Most of which Authours I have perused, and shall willingly acknowledge my self a debtor to them for many things in this following Discourse.

Cap. II.

Concerning the name of this Art. That it may properly be styled liberall. The subject and nature of it.

Lypsius. Polyorcet. l. 1. Dialog 3. That's a senslesse absurd Etymology imposed by some, *Quia intellectus in eis mœchatur*, as if these arts did prostitute and adulterate the understanding.

The word *Mechanick* is thought to be derived ἀπὸ τῦ μήκυς καὶ ἄνευ, *multum ascendere, pertingere:* intimating the efficacy and force of such inventions. Or else παρὰ μὴ χαίνειν, (saith *Eustathius*) *quia hiscere non sinit*, because these arts are so full of pleasant variety, that they admit not either of sloth or wearinesse.

According to ordinary signification, the word is used in opposition to the liberall arts: whereas in propriety of speech those employments alone may be styled *illiberall*, which require onely some bodily exercise, as manufactures, trades, &c. And on the con-

contrary that diſcipline, which diſcovers the generall cauſes, effects, and properties of things, may truly be eſteemed as a *ſpecies* of Philoſophy.

But here it ſhould be noted, that this art is uſually diſtinguiſhed into a twofold kind:

1. *Rationall.*
2. *Cheirurgicall.*

Pappus Proæm. in collect. Mathem. l. 8.

The *Rationall* is that which treats of thoſe principles, and fundamentall notions, which may concern theſe Mechanicall practiſes.

The *Cheirurgicall* or *Manuall*, doth refer to the making of theſe inſtruments, and the exerciſing of ſuch particular experiments. As in the works of Architecture, Fortifications, and the like.

The firſt of theſe, is the ſubject of this diſcourſe, and may properly be ſtyled *liberall*, as juſtly deſerving the proſecution of an ingenuous minde. For if we conſider it according to its birth and originall, we ſhall finde it to ſpring from honourable parentage, being produced by *Geometry* on the one

one ſide, and *naturall Philoſophy* on the other. If according to its uſe and benefit, we may then diſcern that to this ſhould be referred all thoſe arts and profeſſions, ſo neceſſary for humane ſociety, whereby nature is not onely directed in her uſuall courſe, but ſometimes alſo commanded againſt her own law. The particulars that concern Architecture, Navigation, Husbandry, Military affairs, &c. are moſt of them reducible to this art, both for their invention and uſe.

Thoſe other diſciplines of Logick, Rhetorick, &c. doe not more protect and adorn the mind, then theſe Mechanicall powers doe the body.

And therefore are they well worthy to be entertained with greater induſtry and reſpect, then they commonly meet with in theſe times; wherein there be very many that pretend to be maſters in all the liberall arts, who ſcarce underſtand any thing in theſe particulars.

The ſubject of this art is concerning the heavineſſe of ſeverall bodies,

or

or the proportion that is required betwixt any weight, in relation to the power which may be able to move it. And so it refers likewise to violent and artificiall motion, as Philosophy doth to that which is naturall.

The proper end for which this art is intended, is to teach how by understanding the true difference betwixt the *weight* and the *power*, a man may adde such a fitting supplement to the strength of the power, that it shall be able to move any conceivable weight, though it should never so much exceed that force, which the power is naturally endowed with.

The art it self may be thus described, to be a Mathematicall discipline, which by the help of Geometricall principles doth teach to contrive severall weights and powers, unto any kind, either of motion or rest, according as the Artificer shall determine.

If it be doubted how this may be esteemed a *species* of Mathematicks, which as it treats of weights, and not of

Dav. Rivaltus præfat. lib. Archim. de centro gravitatis.

of quantity; For ſatisfaction to this, there are two particulars conſiderable.

1. *Mathematicks* in its latitude is uſually divided into *pure* and *mixed*. And though the *pure* doe handle only *abſtract quantity* in the *generall*, as *Geometry*, *Arithmetick*: yet that which is *mixed* doth conſider the quantity of ſome *particular determinate* ſubject. So *Aſtronomy* handles the quantity of heavenly motions, *Muſick* of ſounds, and *Mechanicks* of weights & powers.

2. Heavineſſe or weight is not here conſidered, as being ſuch a naturall *quality*, whereby condenſed bodies do of themſelves *tend downwards*; but rather as being an affection, whereby they may be meaſured. And in this ſenſe *Ariſtotle* himſelfe referres it amongſt the other *ſpecies* of *quantity*, as having the ſame proper eſſence, which is to be compounded of integrall parts. So a pound doth conſiſt of ounces, drams, ſcruples. Whence it is evident, that there is not any ſuch repugnancy in the ſubject of this art, as may hinder it from being a true *ſpecies* of *Mathematicks*.

Metaph. l. 10. c. 2.

Cap.

Cap. III.

Of the first Mechanical faculty, the Ballance.

THe Mechanicall faculties, by which the experiments of this nature must be contrived, are usually reckoned to be these six:

1. *Libra.*	1. *The Ballance.*
2. *Vectis.*	2. *The Leaver.*
3. *Axis in Peritrochio.*	3. *The Wheel.*
4. *Trochlea.*	4. *The Pulley.*
5. *Cuneus.*	5. *The Wedge.*
6. *Cochlea.*	6. *The Screw.*

Unto some of which, the force of all Mechanicall inventions must necessarily be reduced. I shall speak of them severally and in this order.

First, concerning the Ballance; this, & the Leaver are usually confounded together, as being but one faculty, because the generall grounds & proportions of eithers force is so exactly the same. But for better distinctiō, & more clear

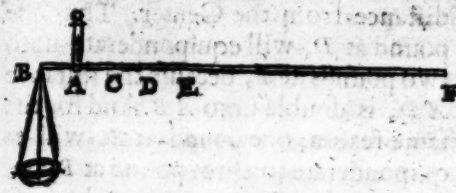
clear discovery of their natures, I shall treat of them severally.

The first invention of the ballance is commonly attributed to *Astrea*, who is therefore deified for the goddesse of justice; and that instrument it self advanced amongst the celestiall signs.

The particulars concerning it are so commonly known, and of such easie experiment, that they will not need any large explication. The chief end and purpose of it, is for the distinction of severall ponderosities; For the understanding of which, we must note, that if the length of the sides in the Ballance, and the weights at the ends of them be both mutually equall, then the Beam will be in a horizontall situation. But on the contrary, if either the weights alone be equall, and not their distances; or the distances alone, and not the weights; then the Beam will accordingly decline.

As in this following diagram.

Sup-



Suppose an equall weight at *C*, unto that at *B*, (which points are both equally distant from the center *A*,) it is evident that then the beam *B F*, will hang horizontally. But if the weight supposed at *C*, be unequall to that at *B*, or if there be an equall weight at *D E*, or any of the other unequall distances; the Beam must then necessarily decline.

With this kinde of Ballance, it is usuall by the help onely of one weight, to measure sundry different gravities, whether more or lesse, then that by which they are measured. As by the example here described, a man may with one pound alone, weigh any other body within ten pounds, because the heavinesse of any weight doth

Cardan. Subtil. l. 1.

doth increaſe proportionably to its diſtance from the Center. Thus one pound at *D*, will equiponderate unto two pounds at *B*, becauſe the diſtance *A D*, is double unto *A B*. And for the ſame reaſon, one pound at *E*, will equiponderate to three pound at *B*, and one pound at *F*, unto ten at *B*, becauſe there is ſtill the ſame diſproportion betwixt their ſeverall diſtances.

This kind of Ballance is uſually ſtyled *Romana*, *ſtatera*. It ſeems to be of ancient uſe, and is mentioned by *Ariſtotle* under the name of [illegible].

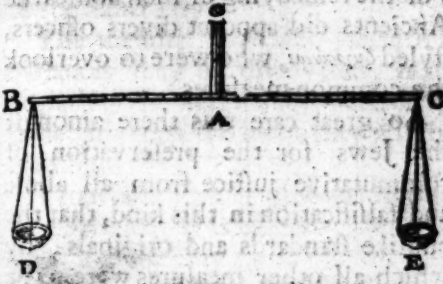
Mechan. ca. 21.

Hence it is eaſie to apprehend, how that falſe ballance may be compoſed ſo often condemned by the wiſe man, as being an abomination to the Lord. If the ſides of the Beam be not equally divided, as ſuppoſe one have 10 parts, and the other 11, then any two weights that differ according to this proportion, (the heavier being placed on the ſhorter ſide, and the lighter on the longer) will equiponderate. And yet both the ſcoles being empty, ſhall hang in *æquilibrio*, as

Prov. 11. 1 *ca.* 16. 11. *Item cap.* 20. 10. 23.

Pappus. Collect. Mathem. l. 8.

as if they were exactly just and true, as in this description.



Suppose *A C*, to have 11 such parts, whereof *A B*, has but 10, and yet both of them to be in themselves of equall weight; it is certain, that whether the scoles be empty, or whether in the scole *D*, we put 11 pound, and at *E*, 10 pound, yet both of them shall equiponderate, because there is just such a disproportion in the length of the sides *A C*, being unto *A B*, as 11 to 10.

The frequency of such cousenages in these days, may be evident from common experience: and that they were used also in former ages, may

Quæstion. Mechan. 6.2. Budæus. Hence the proverb *Zygostatica fides.*

appear from *Aristotles* testimony concerning the Merchants in his time. For the remedying of such abuses the Ancients did appoint divers officers, styled ζυγοστάται, who were to overlook the common measures.

So great care was there amongst the Jews for the preservation of commutative justice from all abuse and falsification in this kind, that the publike standards and originals, by which all other measures were to be tryed and allowed, were with much religion preserved in the sanctuary, the care of them being committed to the Priests and Levites, whose office it was to look unto *all manner of measures and size.* Hence is that frequent expression, *According to the shekel of the Sanctuary*; and that Law, *All thy estimations shall bee according to the shekel of the Sanctuary*, which doth not refer to any weight or coin, distinct from, and more then the vulgar, (as some fondly conceive) but doth onely oblige men in their dealing and traffique to make use of such just

1 Chron. 23.29.

Exod. 30. 13.

Lev. 27.25

juſt measures, as were agreeable unto the publike ſtandards that were kept in the Sanctuary.

The manner how ſuch deceitfull ballances may be diſcovered, is by changing the weights into each other ſcale; and then the inequality will be manifeſt.

From the former grounds rightly apprehended, it is eaſie to conceive how a man may finde out the juſt proportion of a weight, which in any point given, ſhall equiponderate to ſeverall weights given, hanging in ſeverall places of the Beam.

Some of theſe ballances are made ſo exact, (thoſe eſpecially which the refiners uſe) as to be ſenſibly turned with the eightieth part of a grain: which (though it may ſeeme very ſtrange) is nothing to what * *Capellus* relates of one at *Sedan*, that would turne with the four hundredth part of a grain.

Maſter *Greaves* Romane foot.

* *De ponderibus & mensuris.*

There are ſeverall contrivances to make uſe of theſe in meaſuring the weight of blows, the force of powder,

the ſtrength of ſtrings, or other oblong ſubſtances, condenſed air, the diſtinct proportion of ſeverall metals mixed together, the different gravity of divers bodies in the water, from what they have in the open air, with divers the like ingenuous inquiries.

Cap. IV.

Concerning the ſecond Mechanick faculty, the Leaver.

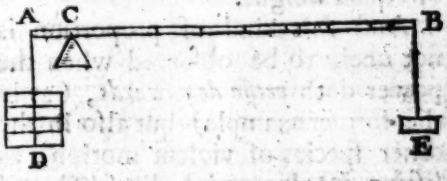
THe ſecond Mechanicall faculty, is the Leaver; the firſt invention of it is uſually aſcribed to *Neptune*, and repreſented by his Trident, which in the Greek are both called by one name, and are not very unlike in form, being both of them ſomewhat broader at one end, then in the other parts.

μόχλος. *Ariſtotle Queſt. Mechan. cap. 4.*

There is one main principle concerning it, which is (as it were) the very ſum and epitome of this whole art. The meaning of it is thus expreſſed by *Ariſtotle*, ὁ τὸ κινοῦντον βάρος πρὸς τὸ κινοῦμενον μῆκος πρὸς τὸ μῆκος ἀντιπεπονθέναι. That is,

Archimedes, de Æquiponderant. Li. prop. 7. Vitruvius Architect. l. 10. c. 8.

is, as the weight is to an equivalent power, so is the distance betwixt the weight and the center, unto the distance betwixt the center and the power, and so reciprocally. Or thus, the power that doth equiponderate with any weight, must have the same proportion unto it, as there is betwixt their severall distances from the center or fulciment: as in this following figure.



Where suppose the Leaver to bee represented by the length *A B*, the center or * prop at the point *C*, the weight to bee sustained *D*, the power that doth uphold it *E*.

Now the meaning of the foresaid principle doth import thus much; that the power at *E*, must bear the

* This Aristotle calls ὑπομόχλιον. Vitruvius, Pressio. Vbaldus Fulcimentum. Dan. Barbarus, Scabellum.

same proportion to the weight *D*, as the distance *C A*, doth to the other *C B*; which, because it is octuple in the present example, therefore it will follow that one pound at *B*, or *E*, will equiponderate to eight pounds at *A*, or *D*, as is expressed in the figure. The ground of which maxime is this, because the point *C*, is supposed to be the center of gravity, on either side of which, the parts are of equall weight.

And this kind of proportion is not onely to be observed when the power doth *presse downwards*, (as in the former example) but also in the other species of violent motion, as *lifting*, *drawing*, and the like. Thus if the prop or fulciment were supposed to be at the extremity of the Leaver,

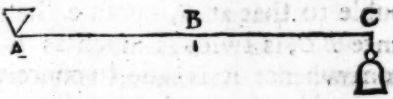
As

As in this Diagram at *A*, then the weighs *B*, would require ſuch a difference in the ſtrengths or powers that did ſuſtain it, as there is betwixt the ſeverall diſtances *A C*, and *B C*. For as the diſtance *A B*, is unto *A C*, ſo is the power at *C*, to the weight at *B*; that is, the power at *A*, muſt bee double to that at *C*, becauſe the diſtance *B C*, is twice as much as *B A*. From whence it is eaſie to conceive, how any burden carried betwixt two perſons, may be proportioned according to their different ſtrengths. If the weight were imagined to hang at the number 2, then the power at *C*, would ſuſtain but two of thoſe parts, whereof that at *A*, did uphold 16. If it be ſuppoſed at the figure (3) then the ſtrength at *C*, to that at *A*, would be but as three to fifteen. But if it were ſituated at the figure (9) then each of the extremities would participate of it alike, becauſe that being the middle, both the diſtances are equall. If at the number (12) then the ſtrength at *C*, is required to be

The right underſtanding of this doth much conduce to the explication of the Pulley.

double unto that at *A*. And in the like manner are we to conceive of the other intermediate diviſions.

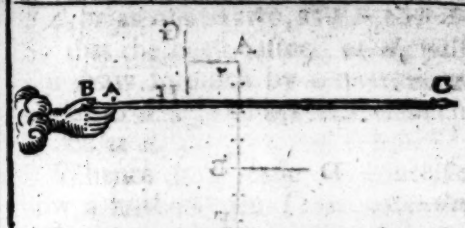
Thus alſo muſt it be, if we ſuppoſe the power to be placed betwixt the fulciment and the weight, as in this example.



Where, as *A C*, is to *A B*, ſo is the power at *B*, to the weight at *C*.

Hence likewiſe may we conceive the reaſon why it is much harder to carry any long ſubſtance, either on the ſhoulders, or in the hand, if it be held by either of the extreams, then if it be ſuſtained by the middle of it. The ſtrength that muſt equiponderate at the nearer end, ſometimes increaſing the weight almoſt double to what it is in it ſelf.

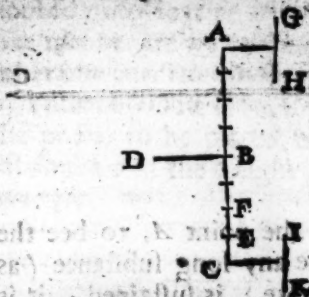
Imagine



Imagine the point *A*, to bee the place where any long ſubſtance (as ſuppoſe a Pike) is ſuſtained; it is evident from the former principle, that the ſtrength at *B*, (which makes it lye levell) muſt be equall to all the length *A C*, which is almoſt the whole Pike.

And as it is in the depreſſing, or elevating, ſo likewiſe is it in the drawing of any weight, as a Coach, Plow, or the like.

Let



Let the line *D B*, represent the Pole or Carriage on which the burden is sustained, and the line *A C*, the crosse barre; at each of its extremities, there is a severall spring-tree *G H*, and *I K*, to which either horses or oxen may be fastned. Now because *A*, and *C*, are equally distant from the middle *B*, therefore in this case the strength must be equall on both sides; but if we suppose one of these spring-trees to bee fastned unto the points *E*, or *F*, then the strength required to draw on that side, will be so much more, as the distance *E B*, or *F B*, is lesse then that of *A B*; that is, either as three to four, as *E B*, to *B A*,

B A, or as one to two, as *F B*, to *B A*. So that the beast fastned at *A*, will not draw so much by a quarter, as the other at *E*, and but half as much as one at *F*.

Whence it is easie to conceive how a husbandman (*cum inæquales veniunt ad aratra juvenci*) may proportion the labour of drawing according to the severall strength of his oxen.

Unto this Mechanicall faculty should bee reduced sundry other instruments in common use. Thus the oares, stearn, masts, &c. according to their force, whereby they give motion to the ship, are to be conceived under this head. *Arist. Mechan. c. 5, 6, 7. Vide Gravar. Comment.*

Thus likewise for that engine, whereby Brewers and Dyers doe commonly draw water, which *Aristotle* calls κοχλίαν, and others *Tollenon*. This being the same kind of instrument, by which *Archimedes* drew up the ships of *Marcellus*. *Mechan. c. 29. Pet. Crinitus, de honesta Disciplina l. 19. c. 2.* calls it corruptly *Tellenon*.

CAP.

Cap. V.

How the naturall motion of living creatures is conformable to these artificiall rules.

THe former principle being already explained, concerning artificiall and dead motions, it will not be altogether impertinent, if in the next place, wee apply it unto those that are naturall in living bodies, and examine whether these also are not governed by the same kinde of proportions.

In all perfect living creatures, there is a twofold kind of motive instruments:

1. Primary, the muscles.
2. Secondary, the members.

The muscles are naturally fitted to be instruments of motion, by the manner of their frame and composure, consisting of flesh as their chief materiall, and besides of Nervs, Ligatures, Veins, Arteries, and Membranes.

The

The *Nervs* ſerve for the conveyance of the motive faculty from the brain. The *Ligatures* for the ſtrengthning of them, that they may not flag and languiſh in their motions. The *Veins* for their nouriſhment. The *Arteries* for the ſupplying of them with ſpirit, and naturall vigor. The *Membranes* for the comprehenſion or incloſure of all theſe together, and for the diſtinction of one muſcle from another. There are beſides divers *fibræ* or hairy ſubſtances, which nature hath beſtowed for the farther corroborating of their motions; theſe being diſperſed through every muſcle, do ſo joyn together in the end of them, as to make intire nervous bodies, which are called *Tendones*, almoſt like the griſles. Now this (ſaith *Galen*) may fitly be compared to the broader part of the Leaver, that is put under the weight, which, as it ought to be ſo much the ſtronger, by how much it is put to a greater force; ſo likewiſe by this, doth nature inable the muſcles and nervs for

De Plæit. Hippoc. & Plato. l. 2. ca. 10.

for those motions, which otherwise would be too difficult for them.

Whence it may evidently appear, that according to the opinion of that eminent Physitian, these naturall motions are regulated by the like grounds with the artificiall.

2. Thus also is it in those secondary instruments of motion, the members: amongst which, the hand is ὄργανον ὀργάνων, the instrument of instruments, (as *Galen* styles it;) and as the soul of man doth bear in it the image of the divine wisdome and providence, so this part of the body seems in some sort to represent the omnipotency of God, whilest it is able to perform such various and wonderfull effects by the help of this art. But now for its own proper naturall strength, in the lifting any great weight, this is always proportioned according to its extension from the body, being of least force when it is fully stretched out, or at arms end, (as we say) because then the shoulder joynt is as the center of its

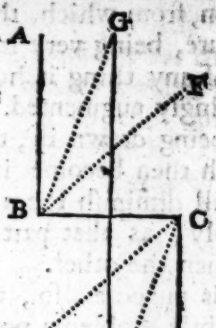
De usu partiū l. 1. c. 2.

its motion, from which, the hand in that posture, being very remote, the weight of any thing it holds must be accordingly augmented. Whereas the arm being drawn in, the elbow joynt doth then become its center, which will diminish the weight proportionably, as that part is neerer unto it then the other.

To this purpose also, there is another subtle probleme proposed by *Aristotle*, concerning the postures of sitting and rising up. The quære is this, Why a man cannot rise up from his seat, unlesse he first, either bend his body forward, or thrust his feet backward. *Mechan. c. 31.*

In the posture of sitting, our legs are supposed to make a right angle with our thighs, and they with our backs, as in this figure.

Where



Where let *A B*, represent the back, *B C*, the thighs, *C D*, the legs. Now it is evident, that a man cannot rise from this posture, unless either the back *A B*, do first incline unto *F*, to make an acute angle with the thighs *B C*; or else that the legs *C D*, do incline towards *E*, which may also make an acute angle with the thighs *B C*; or lastly, unless both of them do decline to the points *G H*, where they may be included in the same perpendicular.

For

For the resolution of which, the Philosopher proposes these two particulars.

1. A right angle (saith he) is a kind of equality; & that being naturally the cause of rest, must needs be an impediment to the motion of rising.

2. Because when either of the parts are brought into an acute angle, the head being removed over the feet, or they under the head; in such a posture the whole man is much neerer disposed to the form of standing, wherein all these parts are in one streight perpendicular line; then he is by the other of right angles, in which the back and legs are two parallels; or that of turning these streight angles into obtuse, which would not make an erect posture but declining.

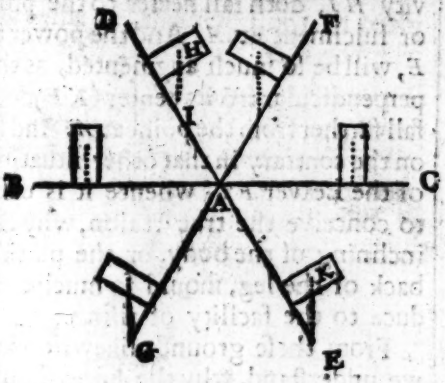
But neither of these particulars (as I conceive) doe fully satisfie the present quære, neither doe the Commentators, *Menanthelius*, or *Guevara*, better resolve it. Rather suppose *BC*, to be as a Vectis or Leaver, to-

wards the middle of which is the place of the fulciment, *A B*, as the weight, *C D*, the power that is to raise it.

Now the body being situate in this rectangular forme, the weight *A B*, must needs be augmented proportionably to its distance from the fulciment, which is about halfe the thighs; whereas if we suppose either the weight to be inclined unto *F*, or the power to *E*, or both of them to *G H*, then there is nothing to bee lifted up but the bare weight it self, which in this situation is not at all increased with any addition by distance.

For in these conclusions concerning the Leaver, we must always imagine that point which is touched by a perpendicular from the center of gravity, to be one of the termes. So that the diverse elevation or depression of the instrument, will inferre a great alteration in the weight it self, as may more clearly be discerned by this following Diagram.

Where



Where *A*, is ſuppoſed to be the place of the prop or fulciment, *B C*, a Leaver which ſtands horizontally, the power and the weight belonging unto it, being equall both in themſelves, and alſo in their diſtances from the prop.

But now ſuppoſe this inſtrument to be altered according to the ſituation *D E*, then the weight *D*, will be diminiſhed, by ſo much, as the perpendicular from its center of gra-

vity *H I*, doth fall nearer to the prop or fulciment at *A*. And the power at *E*, will be so much augmented, as the perpendicular frō its center (*K E*) does fall farther from the point at *A*. And so on the contrary in that other situation of the Leaver *F G*; whence it is easie to conceive the true reason, why the inclining of the body, or the putting back of the leg, should so much conduce to the facility of rising.

Sir *Fran: Bacons Nat. Hist. Exp.* 731.

From these grounds likewise may we understand, why the knees should be most weary in ascending, and the thighs in descending, which is, because the weight of the body doth bear most upon the knee-joynts, in raising it self up, and most upon the muscles of the thighs when it stays it self in comming down.

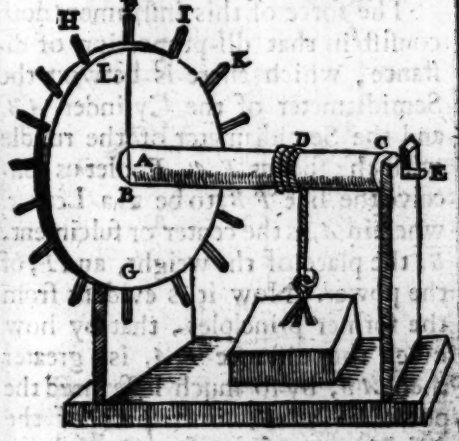
There are divers other naturall problemes to this purpose, which I forbear to recite. We doe not so much as goe, or sit, or rise, without the use of this Mechanicall Geometry.

Cap.

Cap. VI.
Concerning the Wheel.

The third Mechanicall faculty is commonly ſtyled *axis in peritrochio.* It conſiſts of an axis or cylinder, having a rundle about it, wherein there are faſtned divers ſpokes, by which the whole may bee turned round; according to this figure.

Called likewiſe *ὄνος. Ariſt. Mechan. 6.14.*

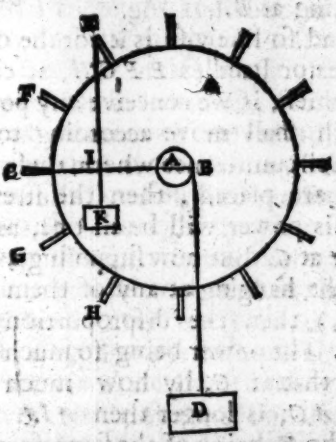


Where *B C*, does represent the Cylinder which is supposed to move upon a smaller Axis at *E*, (this being all one in comparison to the severall proportions, as if it were a meere Mathematicall line) *L G*, is the rundle or wheel, *H F I K*, severall spokes or handles that are fastned in it; *D*, the place where the cord is fastned for the drawing or lifting up of any weight.

The force of this instrument doth consist in that dis-proportion of distance, which there is betwixt the Semidiameter of the Cylinder *A B*, and the Semidiameter of the rundle with the spokes *F A*. For let us conceive the line *F B*, to be as a Leaver, wherein *A*, is the center or fulciment, *B*, the place of the weight, and *F*, of the power. Now it is evident from the former principles, that by how much the distance *F A*, is greater then *A B*, by so much lesse need the power be at *F*, in respect of the weight at *B*. Suppose *A B*, to be as the tenth part of *A F*, then that power

er or ſtrength, which is but as a hundred pound at *F*, will be equall to a thouſand pound at *B*.

For the clearer explication of this faculty, it will not be amiſſe to conſider the form of it, as it will appear being more fully expoſed to the view. As in this other Diagram.



Suppoſe *A B*, for the Semidiameter of the Axis or Cylinder, and *A C*, for the Semidiameter of the rundle, with the ſpokes; then the power

at *C*, which will be able to support the weight *D*, must bear the same proportion unto it, as *AB*, doth to *AC*: so that by how much shorter the distance *AB*, is in comparison to the distance *AC*, by so much lesse need the pow'r be at *C*, which may be able to support the weight *D*, hanging at *B*.

And so likewise is it for the other spokes or handles *EFGH*, at either of which, if we conceive any power, which shall move according to the same circumference wherin these handles are placed, then the strength of this power will be all one, as if it were at *C*. But now supposing a dead weight hanging at any of them, (as at *E*,) then the disproportion will vary. The power being so much lesse then that at *C*, by how much the line *AC*, is longer then *AI*. The weight *K*, being of the same force at *E*, as if it were hung at *I*, in which point the perpendicular of its gravity doth cut the Diameter.

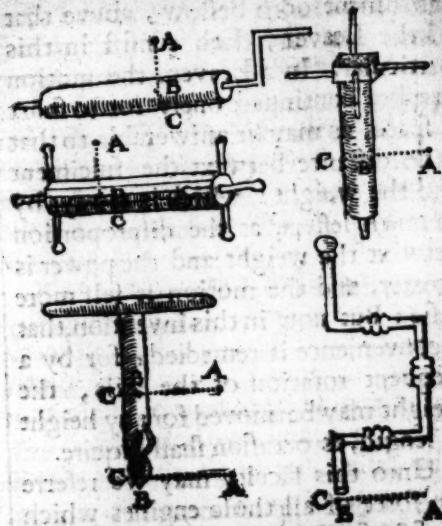
The chief advantage which this in-

inſtrument doth beſtow, above that of the Leaver, doth conſiſt in this particular. In a Leaver, the motion can bee continued onely for ſo ſhort a ſpace, as may be anſwerable to that little diſtance betwixt the fulciment and the weight: which is always by ſo much leſſer, as the diſproportion betwixt the weight and the power is greater, and the motion it ſelf more caſie: But now in this invention, that inconvenience is remedied; for by a frequent rotation of the axis, the weight may be moved for any height or length, as occaſion ſhall require.

Unto this faculty may we referre the force of all thoſe engines which conſiſt of wheels with teeth in them.

Hence alſo may wee diſcerne the reaſon why ſundry inſtruments in common uſe, are framed after the like form with theſe following figures.

All



All which are but ſeverall kinds of this third Mechanicall faculty. In which the points *A B C*, doe repreſent the places of the power, the fulciment, and the weight. The power being in the ſame proportion unto the weight, as *B C* is unto *B A*.

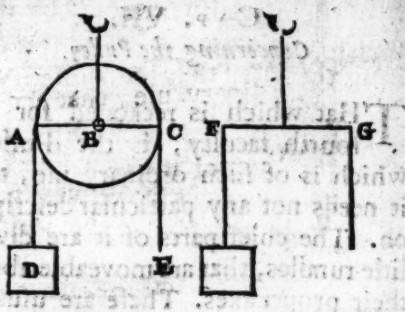
Cap.

Cap. VII.
Concerning the Pulley.

THat which is reckoned for the fourth faculty, is the Pulley: which is of such ordinary use, that it needs not any particular description. The chief parts of it are divers litle rundles, that are moveable about their proper axes. These are usually divided according to their severall situations, into the upper and lower. If an engine have two of these rundles above, and two below, it is usually called δίσπαστος, if three, τρίσπαστος, if many, πολύσπαστος. *Arist. Mechan. c. 19.*

The lower Pulleys onely doe give force to the motion. If we suppose a weight to hang upon any of the upper rundles, it will then require a power, that in it selfe shall be fully equall for the sustaining of it.

The



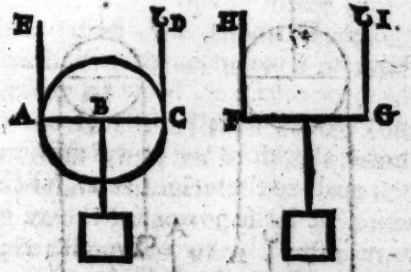
The Diameter *A C*, being as the beam of a ballance, of which *B* is the propor center. Now the parts *A*, and *C*, being equally distant from this center, therefore the power at *E*, must be equall to the weight at *D*, it being all one as if the power and the weight were fastned by two severall strings at the ends of the ballance *F G*.

Now all the upper Pulleys being of the same nature, it must necessarily follow, that none of them doe in themselves conduce to the easing of the power, or lightning the weight, but onely for the greater convenien-

cy

cy of the motion, the cords by this means running more eafily moved then otherwife they would.

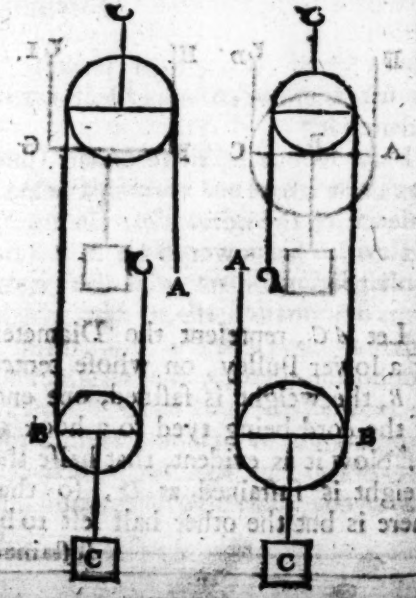
But now fuppofe the weight to be fuftained above the Pulley, as it is in all thofe of the lower fort: and then the power wch fupports it, need be but half as much as the weight it felf.



Let *AC*, repreſent the Diameter of a lower Pulley, on whofe center at *B*, the weight is faſtned, one end of the cord being tyed to a hook at *D*. Now it is evident, that halfe the weight is fuſtained at *D*, ſo that there is but the other half left to be fuſtained

ſuſtained by the power at *E*. It being all one as if the weight were tyed unto the middle of the ballance *FG*, whoſe ends were upheld by two ſeverall ſtrings, *FH*, and *GI*.

And this ſame ſubduple proportion will ſtill remain, though we ſuppoſe an upper Pulley joyned to the lower, as in theſe two other figures,



Where the power at *A*, is equall to the weight at *B*: Now the weight at *B*, being but half the ponderosity *C*, therefore the power at *A*, notwithstanding the addition of the upper rundle, must be equivalent to half the weight; and as the upper Pulley alone, doth not abate anything of the weight, so neither being joyned with the lower, & the same subduple difference betwixt the power and the weight, which is caused by the lower Pulley alone, doth still remain unaltered, though there be an upper Pulley added unto it.

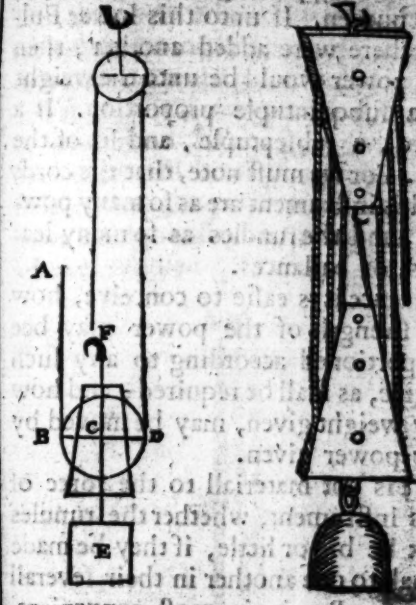
Now as one of these under Pulleys doth abate halfe of that heavinesse which the weight hath in it self, and cause the power to be in a subduple proportion unto it, so two of them doe abate halfe of that which remains, and cause a subquadruple proportion betwixt the weight and the power; three of them a subsextuple, four a suboctuple: and so for five, six, or as many as shall be required, they will all of them diminish the

the weight according to this proportion.

Suppose the weight in it self to be 1200 pound, the applying unto it one of these lower Pulleys, wil make it but as 600, two of them as 300, three of them as 150, &c.

But now, if we conceive the first part of the string to be fastned unto the lower Pulley, as in this other figure at *F*,

then



then the power at *A*, will be in a subtriple proportion to the weight *E*, because the heavineſſe would be then equally divided unto the three points of the lower Diameter *B*, *C*, *D*, each

of them ſupporting a like ſhare of the burden. If unto this lower Pulley there were added another, then the power would be unto the weight in a ſubquintuple proportion. If a third, a ſubſeptuple, and ſo of the reſt. For we muſt note, that the cords in this inſtrument are as ſo many powers, and the rundles as ſo many leavers, or ballances.

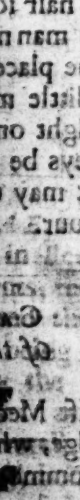
Hence it is eaſie to conceive, how the ſtrength of the power may bee proportioned according to any ſuch degree, as ſhall be required; and how any weight given, may be moved by any power given.

'Tis not materiall to the force of this inſtrument, whether the rundles of it be big or little, if they be made equall to one another in their ſeverall orders; But it is moſt convenient, that the upper ſhould each of them increaſe as they are higher, and the other as they are lower, becauſe by this means the cords will bee kept from tangling.

Theſe Pulleys may be multiplyed ac-

according to sundry different situations, not only when they are subordinate, as in the former examples, but also when they are placed collaterally.

From the former grounds it is easie to contrive a ladder, by which a man may pull himself up unto any height. For the performance of this, there is required only an upper and a lower pulley.



To the uppermost of these at *A*, there should be fastned a sharp graple or cramp of iron, which may be apt to take hold of any place where it lights. This part being first cast up and fastned, and the staffe *D E*, at the nether end, being put betwixt the legs, so that a man may sit upon the other *E C*, and take hold of the cord at *F*. it is evident that the weight of the person at *E*, will be but equall to half so much strength at *F*; so that a man may easily pull himself up to the place required, by leaning but little more then half of his own weight on the string *F*. Or if the Pulleys be multiplyed, this experiment may then be wrought with lesse labour.

Cap. VIII.
Of the Wedge.

THe fift Mechanicall faculty is the Wedge, which is a known instrument, commonly used in the cleaving

ving of wood. The efficacy and great ſtrength of it may be reſolved unto theſe two particulars:

1. The form of it.

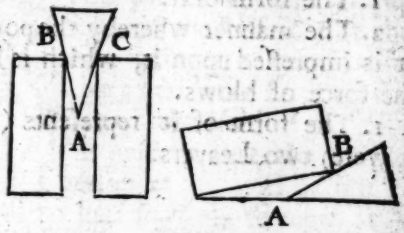
2. The manner whereby the power is impreſſed upon it, which is by the force of blows.

1. The form of it repreſents (as it were) two Leavers.

Each ſide *A D*, and *A E*, being one, the points *B C*, being in ſtead of ſeverall props or fulciments; the weight to be moved at *A*, and the power that ſhould move it, being applyed to the top *D E*, by the force of ſome ſtroake or blow: as *Ariſtotle* hath explained the ſeverall parts of this faculty. But now, becauſe this inſtrument may be ſo uſed that the

Mechan. c.18.

point of it ſhall not touch the body to be moved, as in theſe other figures;



Therefore *Vbaldus* hath more exactly applyed the ſeverall parts of it according to this form, that the point *A*, ſhould be as the common fulciment, in which both the ſides doe meet, and (as it were) uphold one another; the points *B*, and *C*, repreſenting that part of the Leavers where the weight is placed.

It is a generall rule, that the more acute the angles of theſe wedges are, by ſo much more eaſie will their motion be; the force being more eaſily impreſſed, and the ſpace wherein the body is moved, being ſo much the leſſe.

The

The second particular whereby this faculty hath its force, is the *manner* whereby the power is impreſt upon it, which is by a ſtroak or blow, the efficacy of which doth much exceed any other ſtrength. For though we ſuppoſe a wedge being laid on a piece of timber, to be preſſed down with never ſo great a weight; nay, though we ſhould apply unto it the power of thoſe other Mechanicall engines, the Pulley, Screw, &c. yet the effect would be ſcarce conſiderable in compariſon to that of a blow. The true reaſon of which, is one of the greateſt ſubtilties in nature, nor is it fully rendred by any of thoſe who have undertaken the reſolution of it. * *Ariſtotle*, *Cardan*, and *Scaliger*, doe generally aſcribe it unto the ſwiftneſſe of that motion; But there ſeems to be ſomething more in the matter then ſo; for otherwiſe it would follow that the quick ſtroak of a light hammer, ſhould be of greater efficacy, then any ſofter and more gentle ſtriking of a great

* *Mechan. c. 10. Subtil. l. 17 Exercit. 331.*

ſledge. Or according to this, how ſhould it come to paſſe, that the force of an arrow or bullet diſcharged near at hand (when the impreſſion of that violence, whereby they are carried, is moſt freſh, and ſo in probability the motion at its ſwifteſt) is yet notwithſtanding much leſſe then it would be at a greater diſtance. There is therefore further conſiderable, the quality of that inſtrument by which this motion is given, and alſo the conveniency of diſtance through which it paſſes.

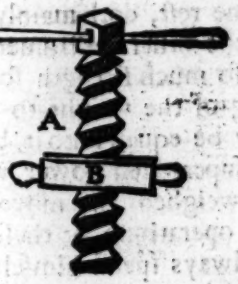
Unto this faculty is uſually reduced the force of files, ſaws, hatchets, &c. which are as it were but ſo many wedges faſtned unto a Vectis or Leaver.

CAP. IX.
Of the Screw.

THat which is uſually recited for the ſixth and laſt Mechanick faculty, is the Screw, which is deſcribed to be a kind of wedge that is multiplyed

plyed, or continued by a helicall revolution about a Cylinder, receiving its motion not from any ſtroak, but from a Vectis at one end of it. It is uſually diſtinguiſhed into two ſeverall kinds: the male, which is meant in the former deſcription, and the female, which is of a concave ſuperficies.

Pappus Collect. Mathemat. l. 8.



The former is noted in the figure with the letter *A*, the other with *F*.

Ariſtotle himſelf doth not ſo much as mention this inſtrument, which yet notwithſtanding is of greater force and ſubtilty, then any of the reſt. It is chiefly applied to the ſqueezing or preſſing of things downe-

wards,

wards, as in the Presses for printing, for wine, oyl, and extracting the juice from other fruits. In the performance of which, the strength of one man may bee of greater force, then the weight of a heavy mountain. It is likewise used for the elevating or lifting up of weights.

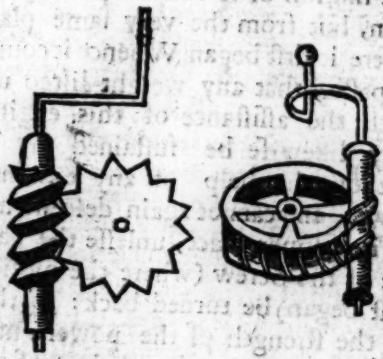
The advantage of this faculty above the rest, doth mainly consist in this: the other instruments doe require so much strength for the supporting of the weight to be moved, as may be equall unto it, besides that other superadded power whereby it is out-weighed and moved; so that in the operations by these, a man does always spend himself in a continued labour.

Thus (for example) a weight that is lifted up by a Wheel or Pulley, will of it self descend, if there bee not an equall power to sustain it. But now in the composure of a Screw, this inconvenience is perfectly remedied; for so much force as is communicated unto this faculty, from the power

power that is applied unto it, is still retained by the very frame and nature of the instrument it self; since the motion of it cannot possibly return, but from the very same place where it first began. Whence it comes to passe, that any weight lifted up, with the assistance of this engine, may likewise be sustained by it, without the help of any externall power, and cannot again descend unto its former place, unlesse the handle of the Screw (where the motion first began) be turned back: so that all the strength of the power, may be imployed in the motion of the weight, and none spent in the sustaining of it.

The chief inconvenience of this instrument is, that in a short space it will be screwed unto its full length, and then it cannot be of any further use for the continuance of the motion, unlesse it be returned back, and undone again as at the first. But this is usually remedied by another invention, commonly styled a *perpetuall*

wall screw, which hath the *motion* of a *wheel*, and the *force* of a *screw*, being both infinite.



For the composure of which, instead of the female, or concave screw, there must be a little wheel, with some notches in it, equivalent to teeth, by which the other may take hold of it, and turn it round, as in these other figures.

It is used in some Watches.

This latter engine does so far exceed all other contrivances to this purpose, that it may justly seem a wonder why it is not of as common use

use in these times and places, as any of the rest.

CAP. X.

An enquiry into the magnificent works of the Ancients, which much exceeding our latter times, may seeme to inferre a decay in these Mechanicall Arts.

THus have I briefly treated concerning the generall principles of Mechanicks; together with the distinct proportions betwixt the weight and the power in each severall faculty of it; Whence it is easie to conceive the truth and ground of those famous ancient monuments, which seem almost incredible to these following ages. And because many of them recorded by Antiquity, were of such vast labour and magnificence, and so mightily disproportionable to humane strength, it shall not therefore be impertinent unto the purpose I aim at, for to specifie some

of the most remarkable amongst them, and to inquire into the means and occasion upon which they were first attempted.

Amongst the *Ægyptians*, we read of divers Pyramids, of so vast a magnitude, as time it self in the space of so many hundred years hath not yet devoured. *Herodotus* mentions one of them, erected by *Cleopes* an Egyptian King, wherein there was not any one stone lesse then 30 foot long, all of them being fetched from *Arabia*. And not much after, the same Authour relates, how *Amasis* another Egyptian, made himself a house of one entire stone, which was 21 cubits long, 14 broad, and 8 cubits high. The same *Amasis* is reported to have made the statue of a *Sphinx*, or Egyptian cat, all of one single stone, whose length was 143 foot, its height 63 foot; the compasse of this statues head containing 102 foot. In one of the Egyptian temples consecrated to *Jupiter*, there is related to be an Obelisk, consisting of 4 Smaragds

Li. 2. c. 175

Plin. l. 36. ca. 12.

Plin. l. 37. cap. 5.

or Emeralds; the whole is 40 cubits high, 4 cubits broad at the bottome, and two at the top. *Sesostris* the King of Ægypt in a Temple at *Memphis*, dedicated to *Vulcan*, is reported to have erected two statues; one for himself, the other for his wife, both consisting of two severall stones, each of which were 30 cubits high. *Diodor. Sicul. Biblioth l.1. Sect.2.*

Amongst the Jews we read in sacred Writ of *Salomons* Temple, which for its state and magnificence, might have been justly reckoned amongst the other wonders of the world, wherein besides the great riches of the materials, there were works too of as great labour. Pillars of brasse 18 cubits high, and 12 cubits round, great and costly stones for the foundation of it. *Josephus* tels us that some of them were 40 cubits, others 45 cubits long. And in the same chapter he mensions the three famous Towres built by *Herod*, wherein every stone being of white marble, was 20 cubits long, 10 broad, and 5 high. And which was the greatest won- *1 Kings 7. 15. cap. 5. v. 17*

De bello Iud. l. 6. c. 6.

wonder, the old wall it ſelf was ſituated on a ſteep riſing ground, and yet the hils upon it, on the tops of wch theſe Towers were placed, were about 30 cubits high, that 'tis ſcarce imaginable by what ſtrength ſo many ſtones of ſuch great magnitude ſhould be conveyed to ſo high a place.

Plin. l. 36. c. 14. Panciroll. Deperd. Tit. 32.

Amongſt the Grecians we read of the *Epheſian* Temple dedicated to *Diana*, wherein there were 127 columnes made of ſo many ſeverall ſtones, each of them 60 foot high, being all taken out of the quarries in *Aſia*. 'Tis ſtoried alſo of the brazen *Coloſſus*, or great ſtatue in the Iſland of *Rhodes*, that it was 70 cubits high. The thumbs of it being ſo big that no man could graſp one of them about with both his arms; when it ſtood upright, a ſhip might have paſſed betwixt the legs of it, with all its ſails fully diſplayed; being thrown down by an earth-quake, the braſſe of it did load 900 Camels. But above all ancient deſigns to this purpoſe, that would have been moſt

Plin. l. 34. c. 3.

wonder-

wonderfull, which a Grecian Architect did propound unto *Alexander*, to cut the mountain *Athos* into the forme of a ſtatue, which in his right hand ſhould hold a Town capable of ten thouſand men, and in his left a Veſſell to receive all the water that flowed from the ſeverall ſprings in the mountain. But whether *Alexander* in his ambition did feare that ſuch an Idoll ſhould have more honour then he himſelf, or whether in his good husbandry, hee thought that ſuch a *Microcoſme* (if I may ſo ſtyle it) would have coſt him almoſt as much as the conquering of this great world, or what ever elſe was the reaſon, he refuſed to attempt it. *Vitruv. Archit. l. 2.*

Amongſt the *Romanes* we read of a brazen *Coloſſus*, made at the command and charges of *Nero*, which was 120 foot high; *Martiall* cals it *Sydereus*, or ſtarry. *Suet. Ner.*

Hic ubi Sydereus propius videt aſtra Coloſſus. And it is ſtoried of *M. Curio*, that he erected two *Theaters* ſufficiently *Pancirol. Depérd. Tit. 18.*

ently capacious of people, contrived moveable upon certain hinges; Sometimes there were severall playes and shows in each of thē, neither being any disturbance to the other; & sometimes they were both turned about, with the people in them, and the ends meeting together, did make a perfect *Amphitheater*: so that the spectators which were in either of them, might joyntly behold the same spectacles.

Id. Tit. 31. There were besides at *Rome* sundry *Obelisks*, made of so many intire stones, some of them 40, some 80, and others 90 cubits high. The chief of them were brought out of *Ægypt*, where they were dug out of divers quarries, & being wrought into form, were afterwards (not without incredible labour, and infinite charges) conveyed unto *Rome*. In the year 1586, there was erected an old *Obelisk*, which had been formerly dedicated unto the memory of *Julius Cæsar*. It was one solid stone, being an Ophite or kind of spotted Marble. The height of it was 107 foot, the breadth of it at

at the bottome was 12 foot, at the top 8. Its whole weight is reckoned to be 956148 pounds, besides the heavineſſe of all thoſe inſtruments that were uſed about it, which (as it is thought) could not amount to leſſe then 1042824 pounds. It was tranſplaced at the charges of Pope *Sixtus* the fifth, from the left ſide of the *Vatican*, unto a more eminent place about a hundred foot off, where now it ſtands. The moving of this *Obelisk* is celebrated by the writings of above 56 ſeverall Authours, (ſaith *Monantholius*) all of them mentioning it, not without much wonder and praiſe. Now if it ſeem ſo ſtrange and glorious an attempt to move this *Obelisk* for ſo little a ſpace, what then may we think of the carriage of it out of Ægypt, and divers other far greater works performed by Antiquity? This may ſeem to infer, that theſe Mechanicall arts are now loſt, and decayed amongſt the many other ruines of time: which yet notwithſtanding cannot be granted, without much ingrati-

Comment. in Mechan. Ariſt. c. 19.

tude to thoſe learned men, whoſe labours in this kind we enjoy, and may juſtly boaſt of. And therefore for our better underſtanding of theſe particulars, it will not be amiſſe to enquire both *why*, and *how*, ſuch works ſhould be performed in thoſe former and ruder ages, which *are not*, and (as it ſhould ſeem) *cannot* be effected in theſe later and more learned times. In the examination of which, wee ſhall finde that it is not the want of art that diſables us for them, ſince theſe Mechanicall diſcoveries are altogether as perfect, and (I think) much more exact now, then they were heretofore; but it is, becauſe we have not either the ſame *motives*, to attempt ſuch works, or the ſame *means* to effect them as the Ancients had.

Cap.

CAP. XI.

That the Ancients had divers motives *and* means *for such vast magnificent works, which we have not.*

THE *motives* by which they were excited to such magnificent attempts, we may conceive to be chiefly three:

Religion.
Policy.
Ambition.

1. *Religion.* Hence was it that most of these stately buildings were intended for some sacred use, being either Temples or * Tombes, all of them dedicated to some of their Deities. It was an in-bred principle in those ancient Heathen, that they could not chuse but merit very much by being liberall in their outward services. And therefore we read of *Cræsus*, that being overcome in a battell, and taken by *Cyrus*, he did revile the gods of ingratitude, because they had no better care of him, who had so frequently

* As Pyramids, Obelisks.

Herodot. l. 1.

adored them with coſtly oblations. And as they did conceive themſelves bound to part with their lives in defence of their religion: ſo likewiſe to employ their utmoſt power and eſtate, about any ſuch deſign, which might promote or advance it. Whereas now, the generality of men, eſpecially the wiſeſt ſort amongſt them, are in this reſpect of another opinion, counting ſuch great and immenſe labours, to be at the beſt but glorious vanities. The Temple of *Solomon* indeed was to be a type, and therefore it was neceſſary that it ſhould be ſo extraordinarily magnificent, otherwiſe perhaps a much cheaper ſtructure might have been as commendable and ſerviceable.

2. *Policy*, that by this means they might find out imployment for the people, who of themſelves being not much civilized, might by idleneſſe quickly grow to ſuch a rudeneſſe and barbariſme, as not to be bounded within any laws of government. Again, by this means the riches of the kingdome

Plin. l. 6. c. 12.

dome did not lye idly in their kings treasuries, but was always in motion, which could not but be a great advantage, and improvement to the Common-wealth. And perhaps some of them feared lest if they should leave too much money unto their successors, it might be an occasion to insnare them in such idle and vain courses, as would ruine their kingdomes. Whereas in these later ages, none of all these politick incitements can be of any force, because now there is imployment enough for all, and mony little enough for every one.

3. *Ambition* to be known unto posterity; and hence likewise arose that incredible labour and care they bestowed, to leave such monuments behinde them, as might * *continue for ever*, and make them famous unto all after ages. This was the reason of *Absalons* pillar, spoken of in Scripture, *to keep his name in remembrance.* And doubtlesse this too was the end which many other of the Ancients have aimed at, in those (as they

* Psal. 49. 11.

2 Sam. 18. 18.

thought) everlasting buildings.

But now these later ages are much more active and stirring: so that every ambitious man may finde so much businesse for the present, that he shall scarce have any leisure to trouble himself about the future. And therefore in all these respects, there is a great disproportion betwixt the incitements of those former and these later times unto such magnificent attempts.

Again, as they differ much in their *motives* unto them, so likewise in the meanes of effecting them.

There was formerly more leisure and opportunity, both for the great men to undertake such works, and for the people to perfect them. Those past ages were more quiet and peaceable, the Princes rather wanting imployment, then being over-prest with it, and therefore were willing to make choice of such great designs, about which to busie themselves: whereas now the world is growne more politick, and therefore more trouble-

troubleſome, every great man having other private and neceſſary buſineſſe about which to imploy both his time and means. And ſo likewiſe for the common people, who then living more wildly without being confined to particular trades and profeſſions, might be more eaſily collected about ſuch famous imployments; whereas now, if a Prince have any occaſion for an Army, it is very hard for him to raiſe ſo great a multitude, as were uſually imployed about theſe magnificent buildings. We read of 360000 men that were buſied for twenty years in making one of the Ægyptian Pyramids. And *Herodotus* tels us of 1000000 men who were as long in building another of them. About the carriage of one ſtone for *Amaſis* the diſtance of twenty days journy, there was for three years together imployed 2000 choſen men, Governours, beſides many other under-labourers. 'Twas the opinion of * *Joſephus* and *Nazianzen*, that theſe Pyramids were built by *Joſeph* for granaries againſt the years

Lib. 2.

* *Antiq. l. 2. c. 5.*

years of famine. Others think that the brick made by the children of *Israel*, was imployed about the framing of them, becauſe we read that the Tower of *Babel* did conſiſt of brick or artificiall ſtone, *Gen.* 11. 3. And if theſe were the labourers that were buſied about them, 'tis no wonder though they were of ſo vaſt a magnitude; for we read that the children of *Israel* at their comming out of Ægypt, were numbred to be ſix hundred thouſand, and three thouſand, and five hundred and fifty men, *Numb.* 1. 46. ſo many handfuls of earth would almoſt make a mountain, and therefore wee may eaſily beleeve that ſo great a multitude in ſo long a ſpace as their bondage laſted, for above four hundred years, might well enough accompliſh ſuch vaſt deſigns.

In the building of *Solomons* Temple, there were threeſcore and ten thouſand that bare burdens, and fourſcore thouſand hewers in the mountains, 1 *Kings* 5. 15.

The *Epheſian* Temple was built by all

all *Asia* joyning together, the 127 pillars were made by so many kings, according to their severall successions, the whole work being not finished under the space of two hundred and fifteen years. Whereas the transplacing of that Obelisk at *Rome* by *Sixtus* the fift, (spoken of before) was done in some few days by five or six hundred men; and as the work was much lesse then many other recorded by Antiquity: so the means by which it was wrought, was yet far lesse in this respect then what is related of them.

2. The abundance of wealth, which was then ingrossed in the possession of some few particular persons, being now diffused amongst a far greater number. There is now a greater equality amongst mankind, and the flourishing of arts and sciences, hath so stirred up the sparks of mens naturall nobility, and made them of such active and industrious spirits, as to free themselves in a great measure from that slavery, which those former and wilder

wilder Nations were subjected unto.

In building one of the Pyramids, there was expended for the maintenance of the labourers, with Radish and Onyons, no lesse then eighteen hundred talents, which is reckoned to amount unto 1880000 crowns, or thereabouts. And considering the cheapnesse of these things in those times and places, so much money might go farther then a summe ten times greater could doe in the maintenance of so many now.

In *Solomons* Temple we know how the extraordinary riches of that King, the generall flourishing of the whole State, and the liberality of the people did joyntly concur to the building of the Temple. *Pecuniarum copia & populi largitas, majora dictu conabatur*, (saith *Josephus*.) The *Rhodian* Colossus is reported to have cost three hundred talents the making. And so were all those other famous monuments of proportionable expence.

De bell. Iud. l. 6. ca. 6.

Pancirollus speaking of those Theaters that were erected at the charges of

of some private Romane Citizens, saith thus: *Nostro hoc sæculo vel Rex satis haberet quod ageret ædificio ejusmodi erigendo*; and a little after upon the like occasion, *Res mehercule miraculosa, quæ nostris temporibus vix à potentissimo aliquo rege posit exhiberi.* *Deperd. Tit. 18.*

3. Adde unto the two former considerations that exact *care* and indefatigable *industry* which they bestowed in the raising of those structures: These being the chief and only designs on which many of them did imploy all their best thoughts and utmost endevours. *Cleopes* an Ægyptian King is reported to have been so desirous to finish one of the Pyramids, that having spent all about it he was worth, or could possibly procure, he was forced at last to prostitute his own daughter for necessary maintenance. And we read of *Ramises* another King of Ægypt, how that he was so careful to erect an Obelisk, about wch he had imployed 20000 men, that when he feared lest through the negligence of the artificers, or weakness of the engine, *Plin. l. 36. c. 9.*

gine, the ſtone might fall and break, he tyed his own ſon to the top of it, that ſo the care of his ſafety might make the workmen more circumſpect in their buſineſſe. And what ſtrange matters may be effected by the meer diligence and labour of great multitudes, we may eaſily diſcern from the wilde Indians, who having not the art or advantage of Engines, did yet by their unwearied induſtry remove ſtones of an incredible greatneſſe. *Acoſta* relates that he himſelf meaſured one at *Tiaguanaco*, which was thirty eight foot long, eighteen broad, and ſix thick, and he affirms that in their ſtatelieſt ædifices, there were many other of much vaſter magnitude.

Hiſtor. Ind. l. 6. c. 14.

From all which conſiderations it may appear, that the ſtrangeneſſe of thoſe ancient monuments above any that are now effected, does not neceſſarily infer any defect of art in theſe later ages. And I conceive, it were as eaſie to demonſtrate the Mechanicall Arts in theſe times to be ſo farre beyond the knowledge of former

ages,

ages, that had we but the ſame means as the Ancients had, we might effect far greater matters then any they attempted, and that too in a ſhorter ſpace, and with leſſe labour.

Cap. XII.

Concerning the force of the Mechanick faculties, particularly the Ballance and Leaver. How they may be contrived to move the whole world, or any other conceivable weight.

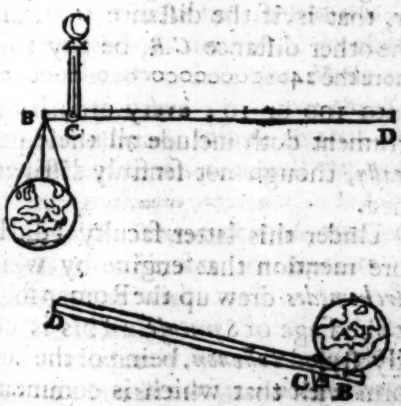
ALL theſe magnificent works of the Ancients before ſpecified, are ſcarce conſiderable in reſpect of art, if we compare them with the famous ſpeeches and acts of *Archimedes:* Of whom it is reported that he was frequently wont to ſay, how that he could move, *Datum pondus cum datâ potentiâ*, The greateſt conceivable weight with the leaſt conceivable power: and that if he did but know where to ſtand and faſten his inſtrument, he could move the world, all this

this great globe of sea and land, which *promises*, though they were altogether above the vulgar apprehension or belief, yet because his *acts* were somewhat answerable thereunto, therefore the King of *Syracuse* did enact a law whereby every man was bound to beleeve, what ever *Archimedes* would affirm.

'Tis easie to demonstrate the Geometricall truth of those strange assertions, by examining them according to each of the forenamed *Mechanick* faculties, every one of which is of infinite power.

To begin with the two first of them, the Ballance and the Leaver, (which I here joyn together, because the proportions of both are wholly alike) 'tis certain, though there should bee the greatest imaginable weight, and the least imaginable power, (suppose the whole world, & the strength of one man or infant) yet if we conceive the same dis-proportion betwixt their severall distances in the former faculties from the fulciment or center of gravity,

vity, they would both equiponderate. And if the distance of the power from the center, in comparison to the distance of the weight, were but any thing more then the heavinesse of the weight is in respect of the power, it may then be evident from the former principles, that the power would be of greater force then the weight, and consequently able to move it.



Thus if we suppose this great globe at *A*, to con-

cõtain 24000000000000000000000000 pounds allowing a hundred pound for each cubicall foot in it, (as *Stevinius* hath calculated) yet a man or childe at *D*, whose strength perhaps is but equivalent to one hundred, or tenne pounds weight, may be able to outweigh and move it, if there be but a little greater disproportion betwixt the two distances *C D*, and *C B*, then there is betwixt the heavinesse of the weight, and the strength of the power, that is, if the distance *C D*, unto the other distance *C B*, be any thing more thẽ 24000000000000000000000000 unto 100 or 10, every ordinary instrument doth include all these parts *really*, though not sensibly distinguished.

Static. l. 3. prop 10.

Under this latter faculty I did before mention that engine by which *Archemedes* drew up the Roman ships, at the siege of *Syracuse*. This is usually styled *Tollenon*, being of the same form with that which is commonly used by Brewers, and Dyers, for the drawing of water. It consists of two posts

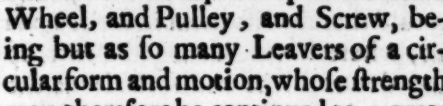
Lipsius Poliorcet. l. 1. Dialog. 6.

posts, the one fastned perpendicularly in the ground, the other being jointed on crosse to the top of it. At the end he fastned a strong hook or grapple of iron, which being let over the wall to the river, he would thereby take hold of the ships, as they passed under; and afterwards by applying some weight, or perhaps the force of Screwes to the other end, hee would thereby lift them into the open air, where having swinged them up and down till he had shaked out the men and goods that were in them, he would then dash the Vessels against the rocks, or drown them in their sudden fall: insomuch that *Marcellus* the Roman Generall was wont to say, τὴν μὲν ναυσὶν αὐτοῦ κυκλίζειν ἐκ θαλάττης Αρχιμήδη, That *Archimedes* made use of his ships in stead of Buckets, to draw water with.

Plutach. in his life.

This faculty will be of the same force, not only when it is continued in one, but also when it is multiplied in divers instruments, as may be conceived in this other form, which I

doe not mention, as if it could be ſerviceable for any motion (ſince the ſpace by which the weight would be moved, will be ſo little as not to fall under ſenſe) but only for the better explication of this Mechanick principle, and for the right underſtanding of that force ariſing from multiplication in the other faculties, which doe all depend upon this. The Wheel, and Pulley, and Screw, being but as ſo many Leavers of a circular form and motion, whoſe ſtrength may therefore be continued to a greater ſpace.



Imagine the weight *A*, to be a hundred thouſand pounds, and the diſtance of that point, wherein every Leaver touches either the weight or one another from the point where they touch the prop, to be but one

ſuch

ſuch part, whereof the remainder contains ten, then according to the former grounds 10000 at *B*, will equiponderate to *A*, which is 100000, ſo that the ſecond Leaver hath but 10000 pounds to move. Now becauſe this obſerves the ſame proportions with the other in the diſtances of its ſeverall points, therefore 1000 pounds at *C*, will be of equall weight to the former. And the weight at *C*, being but as a thouſand pound, that which is but as a hundred at *D*, will be anſwerable unto it; and ſo ſtill in the ſame proportion, that which is but 10 at *E*, will be equall to 100 at *D*; and that which is but one pound at *F*, will alſo be equall to ten at *E*. Whence it is manifeſt, that 1 pound at *F*, is equall to 100000 at *A*; and the weight muſt always be diminiſhed in the ſame proportion as ten to one, becauſe in the multiplication of theſe Leavers, the diſtance of the point, where the inſtrument touches the weight, from that where it touches the prop, is but as one ſuch

part, whereof the remainder contains ten. But now if wee imagine it to be as the thousandth part, then must the weight be diminished according to this proportion; and then in the same multiplication of leavers, 1. will be equall to 1000 000 000 000 000 pounds: so that though we suppose the weight to be never so heavy, yet let the disproportion of distances be greater, or the Leavers more, and any little power may move it.

Cap. XIII.

Of the Wheel, by multiplication of which it is easie to move any imaginable weight.

THe Wheel or *axis in peritrochio*, was before demonstrated to bee of equivalent force with the former faculties. If we conceive the same difference betwixt the Semidiameter of the wheels or spokes *A C*, and the Semidiameter of the axis *A K*, as there is betwixt the weight of the world, and

See the figure cap. 6. pa. 33.

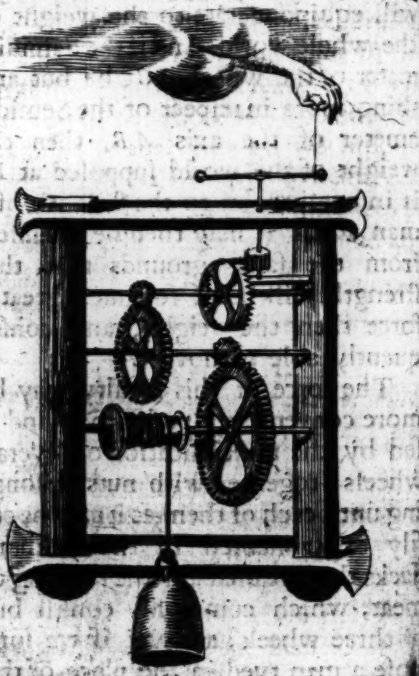
and the ſtrength of a man, it may then be evident, that this ſtrength of one man, by the help of ſuch an inſtrument, will equiponderate to the weight of the whole world. And if the Semidiameter of the wheel *AC*, be but any thing more in reſpect of the Semidiameter of the axis *AB*, then the weight of the world ſuppoſed at *D*, is in compariſon to the ſtrength of a man at *C*; it may then be manifeſt from the ſame grounds that this ſtrength will be of ſo much greater force then the weight, and conſequently able to move it.

The force of this faculty may be more conveniently underſtood and uſed by the multiplication of ſeverall wheels together with nuts belonging unto each of them; as it may be eaſily experimented in the ordinary Jacks that are uſed for the roaſting of meat, which commonly conſiſt but of three wheels, and yet if we ſuppoſe a man tyed in the place of the weight, it were eaſie by a ſingle hair faſtned unto the fly or ballance of the

An engine of many wheels is is commonly called *Glossocomus*.

How to pull a man above ground with a ſingle hair.

Jack, to draw him up from the ground, as will be evident from this following figure.



Where ſuppoſe the length of the fly or ballance in comparison to the breadth of its axis, to be as 10 to one, and ſo for the three other wheels in reſpect of the nuts that belong unto thē; (though this difference be oftentimes leſſe, as we may well allow it to be) withall ſuppoſe the weight (or a man tyed in the place of it) to be a hundred pounds: I ſay according to this ſuppoſition, it is evident that the power at the ballance, which ſhall be equall to the weight, need be but as 1 to 10000. For the firſt axis is conceived to be but as the tenth part of its wheel, and therefore though the weight in it ſelf be as 10000, yet unto a power that hath this advantage, it is but as 1000, and therefore this thouſand unto the like power at the ſecond wheel, will be but as 100, and this 100 at the third but as 10; and laſtly, this ten at the ballance but as one. But the weight was before ſuppoſed to be 100, which to the firſt wheel will be but 10, to the ſecond as one, ſo the third as a deci-

mall,

mall, or one tenth, to the ſails as one hundreth part: ſo that if the hair be but ſtrong enough to lift [illegible] that is, one ten thouſandth part of a man, or (which is all one) one hundreth part of a pound, it may as well ſerve by the help of this inſtrument for the drawing of him up. And though there be not altogether ſo great a diſproportion betwixt the ſeverall parts of a Jack, (as in many perhaps there is not,) and though a man may be heavier then is here ſuppoſed, yet 'tis withall conſiderable that the ſtrength of a hair is able to bear much more then the hundreth part of a pound.

comment. in Gen. c. 1. v. 10. art. 6 De viribus motricibus Theor. 16.

Upon this ground *Merſennus* tels us out of *Solomon de Caus*, that if there were an engine of 12 wheels, each of them with teeth, as alſo the axes or nuts that belong unto them, if the Diameter of theſe wheels were unto each axis, as a hundred to one: and if we ſuppoſe theſe wheels to be ſo placed, that the teeth of the one might take hold of the axis that belongs unto the next, and that the axis

of

of the handle may turn the first wheel, and the weight be tyed unto the axis of the last, with such an engine as this, saith he, a child (if he could stand any where without this earth) might with much ease move it towards him.

For according to the former supposition, that this globe of sea and land, did contain as many hundred pounds, as it doth cubicall feet, *viz.* 24000000000000000000000000, it may be evident that any strength, whose force is but equivalent to 3 pounds, will by such an engine bee able to move it.

Of this kinde was that engine so highly extolled by *Stevinus*, which he calls *Pancration*, or *Omnipotent*, preferring it before the inventions of *Archimedes*. It consisted of wheeles and nuts, as that before specified is supposed. Hither also should be referred the force of racks, which serve for bending of the strongest bowes, as also that little pocket engine whereby a man may break or wrench o-

De Statica praxi.

Ramelli Fig. 180.

pen

pen any dore, together with divers the like instruments in common use.

Cap. XIV.

Concerning the infinite strength of Wheels, Pulleys, & Screws. That it is possible by the multiplication of these, to pull up any Oak by the roots with a hair, lift it up with a straw, or blow it up with ones breath, or to perform the greatest labour with the least power.

FRom what hath been before delivered concerning the nature of the Pulley, it is easie to understand, how this faculty also may be proportioned betwixt any weight, and any power, as being likewise of infinite strength.

'Tis reported of *Archimedes*, that with an engine of Pulleys, to which he applyed onely his left hand, he lifted up * 5000 bushels of corn at once, and drew a ship with all its lading

*7000 saith *Zetzes. Chiliad.* 2. *Hist.* 35.

ding upon dry land. This engine *Zetzes* calls *Trispatum*, or *Trispastum*, which signifies only a threefold Pulley; But herein he doth evidently mistake, for 'tis not possible that this alone should serve for the motion of so great a weight, because such an engine can but make a subsextuple, or at most a subseptuple proportion betwixt the weight and power, which is much too little, to reconcile the strength of a man unto so much heavinesse. Therefore *Vbaldus* doth more properly style it *Polyspaston*, or an instrument of many Pulleys: How many, were easie to find out, if we did exactly know the weight of those ancient measures; supposing them to be the same with our bushell in *England*, which contains 64 pintes or pounds, the whole would amount to 320000 pounds, half of which would be lightned by the help of one Pulley, three quarters by two Pulleys, and so onward, according to this subduple, subquadruple, and subsextuple proportion: So that if we conceive the strength of

Præf. ad Mechan.

of the left hand to be equivalent unto 20 or 40 pounds, it is easie to finde out how many Pulleys are required to inable it for the motion of so great a weight.

Comment. in Gen. c. 1. v. 10. art. 6.

Upon this ground *Mersennus* tels us, that any little childe with an engine of an hundred double Pulleys, might easily move this great globe of earth, though it were much heavier then it is. And in reference to this kind of engine (saith *Monantholius*) are we to understand that assertion of *Archimedes*, (as he more immediately intended it) concerning the possibility of moving the world.

Præf. ad Mechan. Aristotle.

The wedge was before demonstrated to be as a double Vectis or Leaver, and therefore it would be needlesse to explain particularly how this likewise may be contrived of infinite force.

The Screw is capable of multiplication, as well as any of the other faculties, and may perhaps be more serviceable for such great weights, then any of the rest. *Archimedes* his engine

engine of greateſt ſtrength, called *Chariſtion*, is by ſome thought to conſiſt of theſe. *Axes habebat cum infinitis cochleis.* And that other engine of his called *Helix* (mentioned by * *Athenæus*) wherewith he lifted *Hiero's* great ſhip into the ſea, without any other help, is moſt likely to be framed of perpetuall ſcrews, ſaith *Rivaltus*.)

Stevin. de Static. prax. See *Beſſon.*

**Deipnoſophiſt. li. 5.*

Oper. exter. Archimed.

Whence it may evidently appear, that each of theſe Mechanick faculties are of infinite power, and may be contrived proportionable unto any conceivable weight. And that no naturall ſtrength is any way comparable unto theſe artificiall inventions.

'Tis reported of *Sampſon*, that he he could carry the gates of a city upon his ſhoulders, and that the ſtrongeſt bonds were unto him but as flax burnt with fire, and yet his hair being ſhaved off, all his ſtrength departed from him. We * read of *Milo*, that he could carry an Oxe upon his back, and yet when he tried to tear an Oak aſunder

Judg. 15.

* *A. Gell. Noct. Att. l. 15. c. 16.*

der that was somewhat riven before, having drawn it to its utmost, it suddenly joined together again, catching his hands in the cleft, and so strongly manackled him, that he became a prey to the wilde beasts.

But now by these Mechanicall contrivances, it were easie to have made one of *Sampsons* hairs that was shaved off, to have been of more strength, then all of them when they were on. By the help of these arts it is possible (as I shall demonstrate) for any man to lift up the greatest Oak by the roots with a straw, to pull it up with a hair, or to blow it up with his breath.

Suppose the roots of an Oak to extend a thousand foot square, (which is almost a quarter of a mile) and forty foot deep, each cubicall foot being a hundred pound weight; which though it be much beyond the extension of any tree, or the weight of earth, the compasse of the roots in the ground (according to common opinion) not extending further then the branches of it in the air, and the depth

depth of it not above ten foot, beyond which the greateſt rain doth not penetrate (ſaith * *Seneca.*) *Ego vinearum diligens foſſor affirmo nullam pluviam eſſe tam magnam, quæ terram ultra decem pedes in altitudinem madefaciat.* And becauſe the root muſt receive its nouriſhment from the help of ſhowers, therefore it is probable that it doth not goe below them. So that (I ſay) though the proportions ſuppoſed doe much exceed the reall truth, yet it is conſiderable that ſome great overplus muſt be allowed for that labour which there will be in the forcible divulſion or ſeparation of the parts of the earth which are continued.

* *Nat. Qu. l. 3. c. 7.*

According to this ſuppoſition, the work of forcing up the Oak by the roots, will be equivalent to the lifting up of 4000000 pound weight, which by the advantage of ſuch an engine, as is before deſcribed, may be eaſily performed with the leaſt conceivable power.

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The whole force of this engine doth consist in two double Pulleys, twelve wheels, and a sail. One of these Pulleys at the bottome will diminish half of the weight, so that it shall be but as 100000000, and the other Pulley will abate ¾ three quarters of it: so that it shall be but as 1000000000. And because the beginning of the string being fastned unto the lower Pulley, makes the power to be in a subquintuple proportion unto the weight, therefore a power that shall be as 1000000000, that is, a subquadruple, will be so much stronger then the weight, and consequently able to move it. Now suppose the breadth of all the axes and nuts, to be unto the Diameters of the wheel as ten to one, and it will then be evident, that to a power at the first wheel, the weight is but as 100000000. To the second as 10000000. To the third as 1000000. To the fourth as 100000. To the fifth as 10000. To the sixth as 1000. To the seventh as 100. To the eighth

See chap. 7.

as 10. To the ninth as 1. To the tenth as $\frac{1}{10}$, one decimall. To the eleventh as $\frac{1}{100}$. To the twelfth as $\frac{1}{1000}$. And to the ſails yet leſſe. So that if the ſtrength of the ſtraw, or hair, or breath, be but equall to the weight of one thouſandth part of a pound, it may be of ſufficient force to pull up the Oak.

If in this engine we ſuppoſe the diſproportion betwixt the wheeles and nuts, to be as a hundred to one, then it is very evident that the ſame ſtrength of breath, or a hair, or a ſtraw, would be able to move the whole world, as will be eaſily found by calculation. Let this great globe of ſea and land bee imagined (as before) to weigh ſo many hundred pounds as it contains cubicall feet; namely, 24000000000000000000000000 pounds. This will bee to the firſt Pulley, 120000000000000000000000. To the ſecond leſſe thē 600000000000000000000. But for more eaſie and convenient reckoning, let it be ſuppoſed to be ſomewhat more, viz. 1000000000000000000000

This

This to the first wheel will be but as

	10000000000000000000000.
To the second as	1000000000000000000000.
To the third as	100000000000000000000.
To the fourth as	10000000000000000.
To the fifth	1000000000000000.
To the sixth	100000000000000.
To the seventh	10000000000.
To the eighth	1000000000.
To the ninth	1000000.
To the tenth	10000.
To the eleventh	100.
To the twelfth	1.
To the sails as	$\frac{1}{100}$.

So that a power which is much lesse then the hundredth part of a pound will bee able to move the world.

It were needlesse to set down any particular explication, how such Mechanicall strength may be applyed unto all the kinds of locall motion; since this, in it self is so facill and obvious, that every ordinary artificer doth sufficiently understand it.

The species of locall violent motion are by *Aristotle* reckoned to bee these four:

Phyſ. l. 7. c. 3.

Pulſio.
Tractio.
Vectio.
Vertigo.

Thruſting, Drawing, Carrying, Turning. Unto ſome of which all theſe artificiall operations muſt neceſſarily be reduced, the ſtrength of any power being equally applyable unto all of them; So that there is no work impoſſible to theſe contrivances, but there may be as much acted by this art, as can be fancied by imagination.

Cap. XV.

Concerning the proportion of ſlowneſſe and ſwiftneſſe in Mechanicall motion.

HAving already diſcourſed concerning the *ſtrength* of theſe Mechanicall faculties: it remains for the more perfect diſcovery of their natures, that we treat ſomewhat concerning thoſe two differences of artificiall motion:

Slow-

Slowneſſe,
and
Swiftneſſe.

Without the right underſtanding of which, a man ſhall be expoſed to many abſurd miſtakes, in attempting of thoſe things, which are either in themſelves impoſſible, or elſe not to be performed with ſuch means as are applyed unto them. I may ſafely affirm, that many, if not moſt miſtakes in theſe Mechanicall deſigns, doe ariſe from a miſ-apprehenſion of that difference, which there will be betwixt the ſlowneſſe or ſwiftneſſe of the weight and power, in compariſon to the proportion of their ſeverall ſtrengths.

Hence it is, that ſo many engines invented for mines and water-works doe ſo often fail in the performance of that for which they were intended, becauſe the artificers many times doe forget to allow ſo much time for the working of their engine, as may be proportionable to the difference betwixt the weight and power that

belong unto them: whereas he that rightly underſtands the grounds of this art, may as eaſily find out the difference of ſpace and time, required to the motion of the weight and power, as he may their different ſtrengths; and not only tell how any power may move any weight, but alſo in what a ſpace of *time* it may move it any ſpace or *diſtance*.

If it were poſſible to contrive ſuch an invention, whereby any conceivable weight may be moved by any conceivable power, both with the ſame quickneſſe and ſpeed (as it is in thoſe things which are immediately ſtirred by the hand, without the help of any other inſtrument) the works of nature would be then too much ſubjected to the power of art: and men might be thereby incouraged (with the builders of *Babell*, or the rebell Gyants) to ſuch bold deſignes as would not become a created being. And therefore the wiſdome of providence hath ſo confined theſe humane arts, that what any invention hath

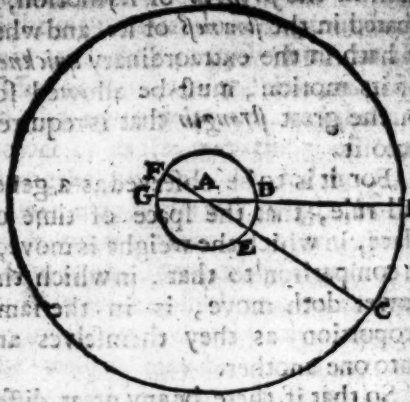
hath in the *ſtrength* of its motion, is abated in the *ſlowneſs* of it: and what it hath in the extraordinary *quickneſs* of its motion, muſt be allowed for in the great *ſtrength* that is required unto it.

For it is to be obſerved as a generall rule, that the ſpace of time or place, in which the weight is moved, in compariſon to that, in which the power doth move, is in the ſame proportion as they themſelves are unto one another.

So that if there be any great difference betwixt the ſtrength of the weight and the power, the ſame kind of differences will there be in the ſpaces of their motion.

To illuſtrate this by an example:

Let



Let the line *G A B*, represent a ballance or leaver, the weight being supposed at the point *G*, the fulciment at *A*, and the power sustaining the weight at *B*. Suppose the point *G*, unto which the weight is fastned, to be elevated unto *F*, and the opposite point *B*, to be depressed unto *C*; 'tis evident that the arch *F G*, or (which is all one) *D E*, doth shew the space of the weight, and the arch *B C*, the motion of the power. Now both

both these arches have the same proportion unto one another, as there is betwixt the weight and the power, or (which is all one) as there is betwixt their severall distances from the fulciment. Suppose AG, unto AB, to be as one unto four, it may then be evident that FG, or DE, will be in the same proportion unto BC. For as any two Semidiameters are unto one another, so are the severall circumferences described by them; as also any proportionall parts of the same circumferences.

And as the weight and power doe thus differ in the spaces of their motions, so likewise in the slowneſſe of it; the one moving the whole distance $B\ C$, in the same time, wherein the other passes onely $G\ F$. So that the motion of the power from B to C, is four times swifter then that of the weight from G to F. And thus will it be, if we suppose the disproportions to be far greater, whether or no we conceive it, either by a continuation of the same instrument and fa-

faculty, as in the former example, or by a *multiplication* of divers, as in Pulleys, Wheels, &c. By how much the power is in it selfe lesse then the weight, by so much will the motion of the weight be slower, then that of the power.

To this purpose I shall briefly touch at one of the Diagrams expressed before in the twelfth Chapter, concerning the multiplication of Leavers.

In which, as each instrument doth diminish the weight according to a decuple proportion, so also doe they diminish the *space* and *slowness* of its motion. For if we should conceive the first Leaver *B*, to be depressed unto its lowest, suppose ten foot, yet the weight *A*, would not be raised

sed above one foot; but now the second Leaver at its utmost could move but a tenth part of the first, and the third Leaver but a tenth part of the second, and so of the rest. So that the last Leaver *F*, being depressed, will passe a *space* 100000 greater, and by a motion, 100000 swifter then the weight at *A*.

Thus are we to conceive of all the other faculties, wherein there is constantly the same disproportiō betwixt the weight and power, in respect of the spaces and slowness of their motions, as there is betwixt their severall gravities. If the power be unto the weight, but as one unto a hundred, then the space through which the weight moves, will be a hundred times lesse, and consequently the motion of the weight a hundred times slower then that of the power.

So that it is but a vain and impossible fancy for any one to think that he can move a great weight with a litle power in a litle space; but in all these Mechanicall attempts, that advantage

vantage which is gotten in the strength of the motion, must be still allowed for in the slowneſſe of it.

Though theſe contrivances doe ſo extreamly increaſe the power, yet they doe proportionably protract the time. That which by ſuch helps one man may doe in a hundred days, may be done by the immediate ſtrength of a hundred men in one day.

Cap. XVI.

That it is poſſible to contrive ſuch an artificiall motion, as ſhall bee of a ſlowneſſe proportionable to the ſwiftneſſe of the heavens.

IT were a pretty ſubtilty to inquire after, whether or no it be not poſſible to contrive ſuch an artificiall motion, that ſhould be in ſuch a proportion ſlow, as the heavens are ſuppoſed to be ſwift.

For the exact reſolution of which, it would be requiſite that we ſhould firſt pitch upon ſome *medium*, or indiffe-

different motion, by the distance from which, we may judge of the proportions on either side, whether slowneſſe or ſwiftneſſe. Now because there is not any ſuch *naturall medium*, which may be absolutely ſtyled an indifferent motion, but that the ſwiftneſſe and slowneſſe of every thing, is ſtill proportioned either to the quantity of bodies, in which they are, or ſome other particular end for which they are designed; therefore we muſt take liberty to ſuppoſe ſuch a motion, and this we may conceive to be about 1000 paces, or a mile in an hower.

The ſtarry heaven, or 8th ſphere is thought to move 42398437 miles in the ſame ſpace: So that if it may be demonſtrated that it is poſſible to contrive ſuch a motion, which going on in a conſtant direct courſe, ſhall paſſe but the 42398437 part of a mile in an hower, it will then be evident, that an artificiall motion may bee ſlow, in the ſame proportion as the heavens are ſwift.

Now

Now it was before manifested that according to the difference betwixt the weight and power, so will the difference be betwixt the slowness or swiftness of their motions, whence it will follow, that in such an engine, wherein the weight shall bee 42398437 pounds, and the power that doth equiponderate it, but the 42398437 part of a pound (which is easie to contrive) in this engine the power being supposed to move with such a swiftnesse, as may be answerable to a mile an hower, the weight will passe but the 42398437 part of a mile in the same space, and so consequently will be proportionably slow unto the swiftnesse of the heavens.

Preface to *Euclid.*

It is related by our Country-man *I. Dee*, that he and *Cardan* being both together in their travels, they did see an instrument which was at first sold for 20 talents of gold, wherein there was one wheel, which constantly moving round amongst the rest, did not finish one revolution under the space of seven thousand years.

But

But if we farther consider such an instrument of wheels as was mentioned before in the 14 chapter, with which the whole world might bee easily moved, we shall then find that the motion of the weight by that, must be much more slow, then the heavens are swift. For though wee suppose (saith *Stevinus*) the handle of such an engine with 12 wheels to be turned about 4000 times in an hower, (which is as often as a mans pulse doth beat) yet in ten years space the weight by this would not be moved above $\frac{1}{12^{12}}$ parts of one foot, which is nothing near so much as a hairs breadth. And it could not passe an inch in 1000000 years, saith *Mersennus*.

De stat. pract.

Phænom. Mechan prop. 11.

The truth of which we may more easily conceive, if we consider the frame and manner of this 12 wheeld engine. Suppose that in each axis or nut, there were ten teeth, and on each wheel a thousand: then the sails of this engine must be turned a hundred times, before the first wheel, (reckoning

ning downward) could bee moved round once, and ten thousand times before the second wheel can finish one revolution, and so through the 12 wheels, according to this multiplyed proportion.

So that besides the wonder wch there is in the force of these Mechanical motions, the extream slownesse of them is no lesse admirable. If a man consider that a body should remaine in such a constant direct motion, that there could not bee one minute of time, wherein it did not rid some space, and passe on further, and yet that this body in many years together, should not move so far as a hairs breadth.

Which notwithstanding may evidently appear from the former instance. For since it is a naturall principle, that there can be no penetration of bodies, and since it is supposed, that each of the parts in this engine doe touch one another in their superficies, therefore it must necessarily follow, that the weight does begin and

and continue to move with the power: and (however it is insensible) yet it is certain there must be such a motion so extreamly slow, as is here specified. So full is this art of rare and incredible subtilties.

I know it is the assertion of *Cardan, Motus valde tardi, necessario quietes habent intermedias.* Extream slow motions have necessarily some intermediate stops and rests: But this is onely said, not proved, and he speaks it from sensible experiments, which in this case are fallible. Our senses being very incompetent judges of the severall proportions, whether greatnesse or littlenesse, slownesse or swiftnesse, which there may bee amongst things in nature. For ought we know, there may be some *Organicall* bodies, as much lesse then ours, as the earth is bigger. We see what strange discoveries of extream minute bodies, (as lice, wheal-worms, mites, and the like) are made by the *Microscope*, wherein their severall parts (which are altogether invisible to the

De varietate rerum l.9.c.47.

bare eye) will distinctly appear: and perhaps there may be other insects that live upon them as they doe upon us. 'Tis certain that our senses are extreamly disproportioned for comprehending the whole compasse and latitude of things. And because there may be such difference in the *motion* as vvell as in the *magnitude* of bodies; therefore, though such extream slowneſſe may seem altogether impossible to sense and common apprehension, yet this can be no sufficient argument against the reality of it.

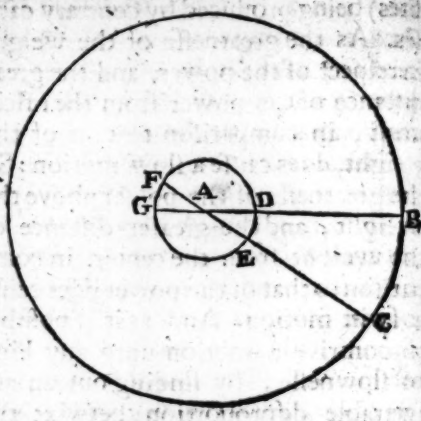
Cap. XVII.

Of swiftneſſe: how it may be increased to any kind of proportion. Concerning the great force of Archimedes *his Engines. Of the Balliſta.*

BY that which hath been already explained concerning the slowness of motion, we may the better understand the nature of swiftneſſe, both of them (as is the nature of oppo-

sites

sites) being produced by contrary causes. As the greatneſſe of the weight in reſpect of the power, and the great diſtance of the power from the fulciment, in compariſon to that of the weight, does cauſe a ſlow motion: So the greatneſſe of the power above the vveight, and the greater diſtance of the vveight from the center, in compariſon to that of the power does cauſe a ſwift motion. And as it is poſſible to contrive a motion unto any kind of ſlowneſſe, by finding out an anſwerable diſproportion betwixt the weight and power: ſo likewiſe unto any kind of ſwiftneſſe. For ſo much as the weight does exceed the power, by ſo much will the motion of the weight be ſlower, and ſo much as the power does exceed the weight, by ſo much vvill the motion of the weight be ſwifter.



In the Diagram ſet down before, if we ſuppoſe *F*, to be the place of the power, and *C* of the weight, the point *A*, being the fulciment or center, then in the ſame ſpace of time, vvherein the power does move from *F*, to *G*, the weight will paſſe from *C*, to *B*. Theſe diſtances having the ſame diſproportion unto one another, as there is betwixt *A F*, and *A C*, which is ſuppoſed to be quadruple. So that in this example, the weight vvill move four

four times swifter then the power. And according as the power does exceed the vveight in any greater disproportion, so will the swiftnesse of the weight be augmented.

Hence may vve conceive the reason of that great force vvhich there is in Slings, vvhich have so much a greater swiftnesse, then a stone thrown from the hand, by how much the end of the Sling is farther off from the shoulder-joynt, vvhich is the center of motion. The sacred history concerning *Davids* victory over *Goliah*, may sufficiently evidence the force of these. *Vegetius* relates that it vvas usuall this vvay to strike a man dead, & beat the soul out of his body, vvithout so much as breaking his armour or fetching blood. *Membris integris lethale tamen vulnus important, & sine invidia sanguinis, hostis lapidis ictu interest.*

1 Sam. 17. 49.

Lipsius Poliorc. l. 4. Dialog. 2.

In the use of these, many of the Ancients have been of very exquisite and admirable skill. We read of *seven hundred Benjamites left-handed, that could sling*

Judges 20. 16.

sling a stone at a hairs breadth, and not misse. And there is the like storied of a whole Nation amongst the Indians, vvho from their excellency in this art were styled *Baleares*. They vvere so strict in teaching this art unto their young ones; *Vt cibum puer à matre non accipit, nisi quem ipsâ monstrante percussit*, That the mother vvould not give any meat to her child, till (being set at some distance) he could hit it with slinging.

ἀπὸ τοῦ βάλλειν. *Diodor. Sicul. Biblioth. l. 5. L. Florus Hist. l. 3. cap. 8. Io: Boemus Aubanus de moribus gentium l. 3. c. 26.*

For the farther illustration of this subject, concerning the *swiftnesse* of motion, I shall briefly specifie some particulars concerning the engines of vvar used by the Ancients. Amongst these, the most famous and admirable vvere those invented by *Archimedes*, by which he did perform such strange exploits, as (vvere they not related by so many and such judicious Authours) vvould scarce seeme credible even to these more learned ages. The acts of that famous Engineer, are largely set down by [a] *Polybius*, [b] *Tzetzes*, [c] *Proclus*, [d] *Plutarch*, [e] *Livy*,

[a] *Histor. l. 4* [b] *Histor. Chilias 2. histor. 35.* [c] *Li. 2. c. 3.* [d] *Marcellus.* [e] *Histor. l. 24.*

vy, and divers others. From the first of whom alone, we may have sufficient evidence for the truth of those relations. For besides that he is an Authour noted to be very grave and serious in his discourse; and does solemnly promise in one place that he will relate nothing, but what either he himself was an eye-witnesse of, or else what hee had received from those that were so; I say, besides all this, it is considerable, that he himself was born not above thirty years after the siege of *Syracuse*. And afterwards having occasion to tarry some weeks in that City, when he travelled with *Scipio*, he might there perhaps see those engines himself, or at least take his information from such as were eye-witnesses of their force. So that there can bee no colourable pretence for any one to distrust the particulars related of them.

Histor. l. 4. juxta initium.

In brief, the sum of their reports is this: When the Romane forces under the conduct of *Marcellus*, had laid siege unto that famous City, (of which

which, both by their former successes, and their present strength, they could not chuse but promise themselves a speedy victory;) yet the arts of this one Mathematician, notwithstanding all their policies and resolutions, did stil beat them back to their great disadvantage. Whether they were neer the wall or farther from it, they were still exposed to the force of his engines, καὶ μακρὰν ἀφεστῶτας καὶ συνέγγυς ὄντας, οὐ μόνον ἀπράκτους παρεσκεύαζε πρὸς τὰς ἰδίας ἐπιβολὰς, ἀλλὰ καὶ διεφθείρε τοὺς πλείστους αὐτῶν. From the multitude of those stones and arrows, which he shot against them, was he styled ἑκατόγχειρ, or *Briareus*. Those defensive engines that were made by the Romanes in the form of Pent-houses for to cover the assailants from the weapons of the besieged, these would he presently batter in pieces vvith great stones and blocks. Those high towers erected in some of the ships, out of which the Romanes might more conveniently fight with the defendants on the wall, these also were so

Cæl: Rhod: Ant: lect: l. 2. c. 16. Pluteus Testudo.

so broken by his engines, that no Cannon or other instrument of Gunpowder, (saith a learned man) had they beene then in use, could have done greater mischief. In brief, hee did so molest them with his frequent and prodigious batteries, that the common soldiers were utterly discouraged from any hopes of successe.

Sir Walt: Raleigh hist. l. 5. c. 3. § 16.

What was the particular frame and manner of these engines cannot certainly be determined, but to contrive such as may perform the like strange effects, were not very difficult to any one who is thoroughly versed in the grounds of this art. Though perhaps those of *Archimedes* in respect of divers circumstances, were much more exact and proper for the purposes to which they were intended, then the invention of others could be, He himself being so extraordinarily subtle and ingenious above the common sort of men.

'Tis probable, that the generall kind of these engines, were the same with those that were used afterwards

wards amongst the Romanes and other Nations. These were commonly divided into two sorts: styled

{ *Ballista.*
{ *Catapulta.*

Both which names are sometimes used promiscuously; but according to their propriety † *Ballista* does signifie an engine for the shooting of stones, and *Catapulta* for darts or arrows.

Vid. Naudæum de Stud. Militar. l. 2.

† ἀπὸ τῦ βάλλειν, called also λιθόβολος. πετροβόλος. *Fundibalus. Petraria.*

The former of these was fitted either to carry divers lesser stones, or else one greatest one. Some of these engines made for great stones, have been proportioned to so vast and immense a weight, as may seem almost incredible: which occasioned that in *Lucan*,

Lib. 3.

At saxum quoties ingenti verberis ictu
Excutitur, qualis rupes quã vertice montis
Abscidit impulsu ventorũ adjuta vetustas,
Frangit cuncta ruẽs; nec tantũ corpora pressa
Exanimat, totos cũ sanguine dissipat artus.

With these, they could easily batter down the vvals and Towers of any Fort: So *Ovid.*

Quam

Quam grave balliſtæ mœnia pulſat onus.

And *Statius*--- *Quo turbine bellica quondam*
Librati ſaliunt portarum in clauſtra molares.

The ſtones that were caſt from theſe, were of any form, *Enormes & ſepulchrales*, Milſtones or Tombe-ſtones. Sometimes for the farther annoyance and terror of any beſieged place, they would by theſe throw into it dead bodies, either of men or horſes, and ſometimes only parts of them as mens heads. *Lipſius Poliorcet. l. 3. Dial. 3.*

Athenæus mentions one of theſe *Balliſtæ* that was proportioned unto a ſtone of three talents vveight, each talent being 120 pounds (ſaith *Vitruvius*) ſo that the vvhole vvill amount to 360 pounds. But it is ſtoried of *Archimedes*, that he caſt a ſtone into one of *Marcellus* his ſhips, which was found to weigh ten talents. There is ſome difference amongſt,* Authors, concerning what kind of talent this ſhould be underſtood, but it is certain that *Deipnoſoph. l. 5. Archit. l. 10. c. ult. λίθον πεντάλαντον. Plut. Marcell. * Dav. Rivaltus Comm. in Archim. Oper. Ext.*

Naudæus de studio. Milit. l. 2.

that in *Plutarchs* time, (from whō we have this relatiō) one talēt did amount to 1200 pounds (saith *Suidas*:) according to vvhich account, the ſtone it ſelf was of no leſſe then twelve hundred pound weight. A weapon (one would think) big enough for thoſe rebell Gyants that fought againſt the gods. Now the greateſt Cannon in uſe, does not carry above 64 pound vveight, which is far ſhort of the ſtrength in theſe Mathematicall contrivances. Amongſt the Turks indeed, there have been ſometimes uſed ſuch powder inſtruments, as may equall the force of thoſe invented by *Archimedes*. *Gab. Naudæus* tels us of one bullet ſhot from them at the ſiege of *Conſtantinople*, which was of above 1200 pound vveight; This he affirms from the relation of an Archbiſhop, who was then preſent and did ſee it; the piece could not be drawn by leſſe then a hundred and fifty yoak of oxen, vvhich might almoſt have ſerved to draw away the Town it ſelfe. But though there hath been perhaps ſome

De Stud. Milit. l. 2.

one

one or two Cannons of such a prodigious magnitude, yet it is certain that the biggest in common use, does come far short of that strength, which was ordinarily in these Mechanical engins.

There are divers figures of these *Ballistæ*, set out by *Vegetius*, *Lipsius*, and others; but being without any explication, it is not very facil to discover in what their forces did consist.

See *Rob: Valturius de re Milit. l. 10. c. 1.*

I have here expressed one of them most easie to be apprehended, from the understanding of which, you may the better ghesse at the nature of the rest.

That

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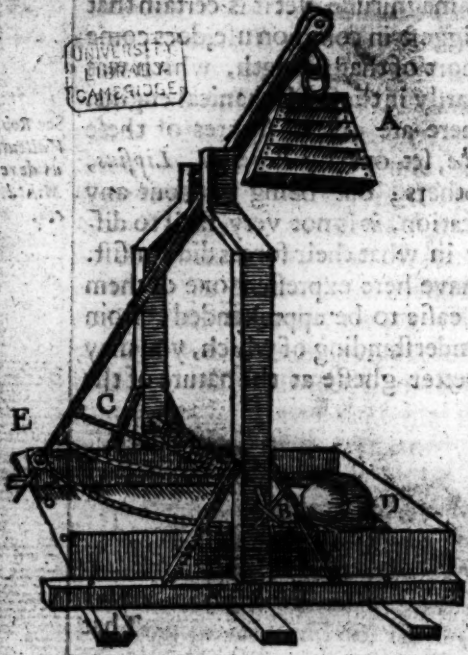


That great box or cavity at *Ai*, is supposed to be full of some heavy weight, and is forced up by the turning

ning of the axis and spokes *B C*. The stone or bullet to be discharged being in a kind of sling at *D*, which when the greater weight *A*, descends, will be violently whirled upwards, till that end of the sling at *E*, coming to the top will flye off, and discharge the stone as the skilfull Artist should direct it.

Cap. XVIII.

Concerning the Catapulta, or Engines for Arrows.

THe other kind of engine was called *Catapulta*, ἀπὸ τοῦ πάλλω, which signifies a spear or dart, because it was used for the shooting of such weapons: some of these were proportioned unto spears of twelve cubits long; they did carry with so great a force, *ut interdum nimio ardore scintillant*, (saith *Ammianus*) that the weapons discharged from them were sometimes (if you can beleeve it) set on fire by the swiftnesse of their motion.

In Greek καταπάλτης. *Athenæus Deipnos. l. 5.*

Lib. 23.

Lipsius Poliorcet. l. 3. Dial. 2.

Diod. Sicul. Biblioth. l. 14. Sardus de Invent. Rerum. l. 2.

The first invention of these is commonly ascribed to *Dionysius* the yonger, who is said to have made them amongst his other preparations against *Carthage*. But we have good reason to think them of more ancient use, because we read in Scripture that *Vzziah made in Jerusalem engines invented by cunning men to shoot arrows and great stones withall*, though it is likely these inventions were much bettered by the experience of after ages.

2 Chron. 26. 15.

The usuall form of these *Catapultæ*, was much after the manner of great Bows placed on Carriages, and wound up by the strength of severall persons. And from that great force which we find in lesser Bows, we may easily gheſſe at the greater power of these other engines. 'Tis related of the Turkish Bow, that it can strike an arrow through a peece of steel or brasse two inches thick, and being headed onely with wood, it pierces Timber of eight inches. Which though it may seem incredi-

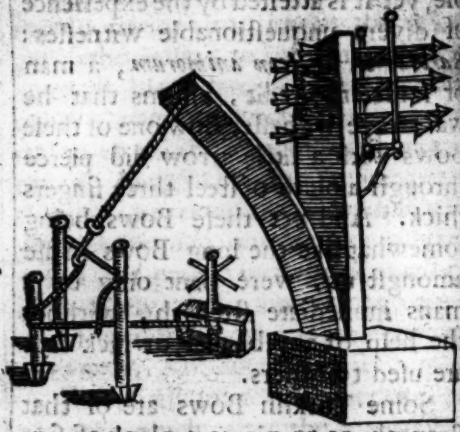
Sir Fran: Bacon Nat. Hist. Exp. 704.

ble,

ble, yet it is atteſted by the experience of divers unqueſtionable witneſſes: *Barclay* in his *Icon animorum*, a man of ſufficient credit, affirms that he was an eye-witneſſe, how one of theſe Bows with a little arrow did pierce through a piece of ſteel three fingers thick. And yet theſe Bows being ſomewhat like the long Bows in uſe amongſt us, were bent only by a mans immediate ſtrength, without the help of any bender or rack that are uſed to others.

Some Turkiſh Bows are of that ſtrength, as to pierce a plank of ſixe inches in thickneſſe, (I ſpeak what I have ſeen) ſaith *M. Po: Greaves* in his *Pyramidographia*. How much greater force then may we conceive to be impreſſed by the *Catapulta*?

Theſe were ſometimes framed for the diſcharging of two or three arrows together, ſo that each of them might bee directed unto a ſeverall aim. But it were as eaſie to contrive the after the like manner for the carriage of twenty arrows, or more, as in this figure.



Both these kinds of engines when they were used at the siege of any City, were commonly carried in a great wooden Turret (first invented by * *Demetrius*.) It was driven upon four wheels at the bottome, each of its sides being forty five cubits, its height ninety. The whole was divided in nine severall partitions, every one of which did contain divers engines for battery: from its use in the battering and taking of Cities it is styled

* Who was therefore styled *Poliorcetes*. This kind of Turret was first used at the siege of *Cyprus*, & is thus described by *Diodorus Sicul. Bibliath. l.* 20.

ſtyled by the name of *Helepolis*.

He that would be informed in the nature of Bows, let him conſult *Merſennus De Balliſtica & Acontiſmologia*, where there are divers ſubtle inquiries and demonſtrations, concerning the ſtrength required to the bending of them to any diſtance. The force they have in the diſcharge according to ſeverall bents, the ſtrength required to be in the ſtring of them, the ſeverall proportions of ſwiftneſſe and diſtance in an arrow ſhot vertically, or horizontally, or tranſverſally.

Thoſe ſtrange effects of the Turkiſh Bow (mentioned before) ſo much exceeding the force of others, which yet require far greater ſtrength for the bending of them, may probably be aſcribed either to the naturall cauſe of *attraction by ſimilitude of ſubſtance*, (as the Lord *Bacon* conjectures.) For in theſe experiments the head of the arrow ſhould be of the ſame ſubſtance (whether ſteel or wood) with that which it pierces: Or elſe to that *juſt proportion* betwixt the

weighs of the arrow, and the strength of the bow, which must needs much conduce to the force of it, and may perhaps be more exactly discovered in these, then it is commonly in others.

Cap. XIX.

A comparison betwixt these ancient engines, and the Gun-powder instruments now in use.

IT shal not be altogether impertinent to inquire somewhat concerning the advantages and disadvantages betwixt those Military offensive engines, used amongst the Ancients, and those of these later ages.

In which inquiry there are two particulars to be chiefly examined:

1. The force of these severall contrivances, or the utmost that may be done by them.

2. Their price, or the greatnesse of the charges required unto them.

1. As for the force of these anci-

ent

ent inventions, it may sufficiently appear from those many credible relations mentioned before; to which may be added that in *Josephus*, which he sets down from his own eye-sight, being himself a chief Captain at the siege of *Jotapata*, where these events happened. He tells us that besides the multitude of persons, who were slain by these Romane Engines, being not able to avoid their force, by reason they were placed so far off, and out of sight; Besides this, they did also carry such great stones, with so great a violence, that they did therewith batter down their walls and Towers. A great bellied woman walking about the City in the day time, had her child struck out of her wombe, and carried half a furlong from her. A soldier standing by his Captain *Josephus*, on the wall, had his head struck off by another stone sent from these Romane Engines, and his brains carried three furlongs off. *De bello Iudaico, l. 3. c. 9.*

To this purpose *Cardan* relates out of *Ammianus Marcellinus*. *Tanto impetu* *De variet. l. 12. c. 58.*

impetu fertur lapis ut uno viſo lapide quamvis intacti barbari fuerint ab eo, deſtiterunt à pugnâ & abierunt. Many forain people being ſo amazed at the ſtrange force of theſe Engines, that they durſt not conteſt with thoſe who were maſters of ſuch inventions. 'Tis frequently aſſerted, that bullets have been melted in the air, by that extremity of violent motion impreſt from theſe ſlings.

Fundáque contorto tranſverberat aëra plumbo,
Et mediis liquidæ glandes in nubibus errant.

So *Lucan*, ſpeaking of the ſame Engines.

Indè faces & ſaxa volant, ſphæraque ſolutæ
Aëris & calidâ liquefactæ pondere glandes.

Which relations, though they may ſeem ſomewhat poeticall and improbable, yet *Ariſtotle* himſelf (*De cælo lib.*2.*c.*7.) doth ſuppoſe them as unqueſtionable. From whence it may be inferred, that the force of theſe Engines

gines does rather exceed then come short of our Gun-powder inventions.

Add to this that opinion of a learned man (which I cited before) that *Archimedes* in the siege of *Syracuse*, did more mischief with his Engines, then could have been wrought by any Cannons, had they been then in use.

Sir Walt. Raleigh. Hist. l. 5. c. 3. § 16. See Lipsius de militiâ Romanâ. l. 5.

In this perhaps there may be some disadvantage, because these Mathematicall Engines cannot be so easily and speedily wound up, and so certainly levelled as the other may.

2. As for the price or charges of both these, it may be considered under three particulars:

1. Their making.
2. Their carriage or conveyance.
3. Their charge and discharging.

In all which respects, the Cannons now in use, are of much greater cost then these other inventions.

1. The making or price of these Gun-powder instruments is extreamly expensive, as may be easily judged by the weight of their materials. A whole Cannon

Cannō weighing commonly 8000 l. a half Cannon 5000, a Culverin 4500, a Demiculverin 3000; which whether it be in iron or braſſe, muſt needs be very coſtly, only for the matter of them; beſides the farther charges required for the form and making of them, which in the whole muſt needs amount to ſeverall hundred pounds. Whereas theſe Mathematicall inventions conſiſting chiefly of Timber, and cords, may be much more cheaply made; The ſeverall degrees of them which ſhall anſwer in proportion to the ſtrength of thoſe other, being at the leaſt ten times cheaper; that is, ten Engines that ſhall be of equal force either to a Cannon or Demicannon, Culverin or Demiculverin, may be framed at the ſame price that one of theſe will amount to: So that in this reſpect there is a great inequality.

2. As for their carriage or conveyance; a whole Cannon does require at the leaſt 90 men, or 16 horſes, for the draught of it; a half Cannon 56 men,

men, or 9 horſes; a Culverin 50 men, or 8 horſes; a Demiculverin 36 men, or 7 horſes; Suppoſing the way to be hard and plain, in which notwithſtanding the motion wil be very ſlow. But if the paſſage prove riſing and ſteep, or rotten and dirty, then they will require a much greater ſtrength and charge for the conveyance of them. Whereas theſe other inventions are in themſelves more light (if there be occaſion for the draught of them) being eaſily taken aſunder into ſeverall parts. And beſides, their materials are to be found every where, ſo that they need not be carried up and down at all, but may be eaſily made in the place where they are to be uſed.

3. The materials required to the charging of theſe Gun-powder inſtruments, are very coſtly. A whole Cannon requiring for every charge 40 pound of powder, and a bullet of 64 pounds; a half Cannon 18 pound of powder, and a bullet of 24 pounds, a Culverin 16 pounds of powder, and

a

a bullet of 19 pounds; a Demi-culverin 9 pounds of powder, and a bullet of 12 pounds: whereas those other Engines may be charged only with stones, or (which may serve for terrour) with dead bodies, or any such materials as every place will afford without any cost.

So then, put all these together: If it be so that those ancient inventions did not come short of these other in regard of force, and if they doe so much excell them in divers other respects; It should seem then, that they are much more commodious then these later inventions, and should be preferred before them. But this inquiry cannot be fully determined without particular experience of both.

CAP.

Cap. XX.

That it is possible to contrive such an artificiall motion, as may be equally swift with the supposed motion of the heavens.

For the conclusion of this Discourse, I shall briefly examine (as before concerning slowness) whether it be possible to contrive such an artificiall motion, as may be equall unto the supposed swiftness of the heavens. This question hath been formerly proposed and answered by *Cardan*, where he applies it unto the swiftness of the moons orb; but that orb being the lowest of all, and consequently of a dull and sluggish motion, in comparison to the rest; therefore it will perhaps be more convenient to understand the question concerning the eight sphere or starry heaven. *De Variet. Rerum l. 9. c. 47.*

For the true resolution of this, it should be first observed, that a materiall substance is altogether incapable

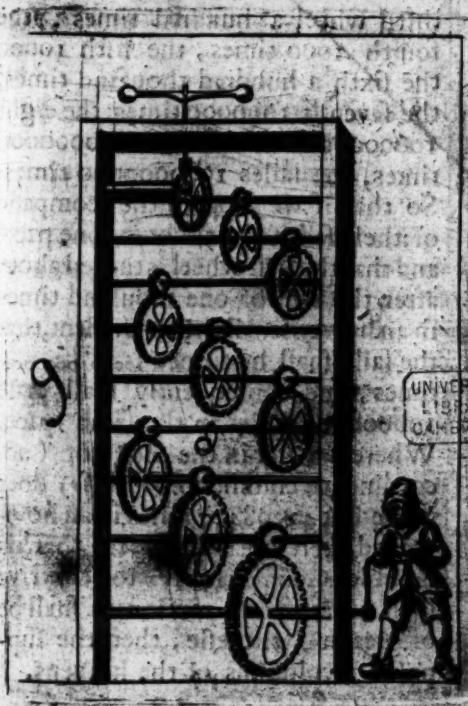
The earth a planet, *prop.* 9.

ble of so great a celerity, as is usually ascribed to the celestiall orbs. (as I have proved elsewhere) And therefore the quære is not to be understood of any reall and experimentall, but only notionall, and Geometrical contrivance.

Now that the swiftnesse of motion may be thus increased, according to any conceivable proportion, will be manifest from what hath been formerly delivered, concerning the grounds and nature of slownesse and swiftnesse. For according as we shall suppose the power to exceed the weight: so may the motion of the weight be swifter then that of the power.

But to answer more particularly: Let us imagine every wheel in this following figure to have a hundred teeth in it, and every nut ten

It



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It may then bee evident, that one revolution of the first wheel, will turn the nut, and consequently the second wheel on the same axis ten times, the third

third wheel a hundred times, the fourth 1000 times, the fifth 10000 the sixth a hundred thousand times, the seventh 1000000 times, the eight 10000000 times the ninth 100000000 times, the sailes 1000000000 times: So that if we suppose the compasse of these sails to be 5 foot, or one pace: and that the first wheel is turned about after the rate of one thousand times in an hower: It wil thé be evident, that the sails shall be turned 1000000000000. times, and consequently shall passe 100000000 miles in the same space. Whereas a star in the Æquator (according to common *Hypothesis*) does move but 42398437 miles in an hower, and therefore it is evident that 'tis possible Geometrically to contrive such an artificiall motion, as shall be of greater swiftnesse, then the supposed revolutions of the heavens.

DÆDA-

DÆDALVS, OR, MECHANICALL Motions.

Chap. I.

The divers kinds of Automata, *or Self-movers. Of Mils, and the contrivance of severall motions by rarefied air. A brief digressiõ concerning wind-guns.*

AMongst the variety of artificiall motions, those are of most use and pleasure, in which, by the application of some continued strength, there is bestowed a regular and lasting motion.

These we call the αὐτόματα, or *self-movers:* which name in its utmost latitude, is sometimes ascribed unto those motions, that are contrived from the strength of living creatures, as Chariots, Carts, &c. But in its strictnesse & propriety, it is onely appliable unto such inventions, wherein the motiõ is caused either by somthing that belongs unto its own frame, or

else by some external inanimate agent.

Whence these ἀυτόματα are easily distinguishable into two sorts:

1. Those that are moved by something which is extrinsecall unto their own frame, as Mils by water or wind.

2. Those that receive their motion from something that does belong to the frame it self, as clocks, watches, by weights, springs, or the like.

Of both which sorts, there have been many excellent inventions: In the recitall of them, I shall insist chiefly on such as are most eminent for their rarity and subtilty.

Amongst the ἀυτόματα that receive their motion frō some externall agent, those of more common use are Mils.

And first, the Water-mils, which are thought to be before the other, though neither the first Author, nor so much as the time wherein they were invented is fully known. And therefore *Polydor Virgil* refers them amongst other fatherlesse inventions. *Pliny* indeed doth mention them, as being commonly used in his time: and yet others

De invent. Rerum l. 3. c. 18. Nat. Hist. l. 18. c. 10.

others affirm, that *Belliſarius* in the reign of *Iuſtinian*, did firſt invent them; Whence *Pancirollus* concludes that it is likely their uſe was for ſome ſpace intermitted, and being afterwards renued again, they were then thought to be firſt diſcovered. *De Repert. Tit. 22.*

However 'tis certain, that this invention hath much abridged and advantaged the labours of men, who were before condemned unto this ſlavery, as now unto the Galleys. And as the force of waters hath been uſefull for this, ſo likewiſe may it be contrived to divers other purpoſes. Herein doth the skill of an artificer chiefly conſiſt, in the application of theſe common motions unto various and beneficiall ends, making them ſerviceable not only for the grinding of corn, but for the preparing of iron or other ware, the making of paper, the elevating of water or the like. *Ad Piſtrinum.*

To this purpoſe alſo are the Mils that are driven by wind, which are ſo much more convenient then the other, by how much their ſituations

may be more easie and common. The motions of these may likewise be accommodated to as various uses as the other, there being scarce any labour, to the performance of which, an ingenious artificer cannot apply them. To the sawing of Timber, the plowing of land, or any other the like service, which cannot be dispatched the ordinary way, without much toil and tediousnesse. And it is a wonderfull thing to consider, how much mens labours might be eased and contracted in sundry particulars, if such as were well skilled in the prinples and practises of these Mechanicall experiments, would but thoroughly apply their studies unto the inlargement of such inventions.

There are some other motions by wind or air, which (though they are not so common as the other, yet) may prove of excellent curiosity, and singular use. Such was that musicall instrument invented by *Cornelius Dreble*, which being set in the sun-shine, would of it self render a soft and pleasant

Marcell. Frankbein. Epist. ad Iob. Ernestum.

pleasant harmony, but being removed into the shade, would presently become silent. The reason of it was this: the warmth of the sun, working upon some moisture within it, and rarifying the inward air unto so great an extension, that it must needs seek for vent or issue, did therby give severall motions unto the instrument.

Like that statue of *Memnon* in Ægypt, which makes a strange noise when ever the sun begins to shine upon it. *Tacit. Anal. 2. Strabo* affirms that he had both seen and heard it.

Somewhat of this nature are the *Æolipiles*, which are concave vessels, consisting of some such materiall as may indure the fire, having a small hole, at which they are filled with water, and out of which (when the Vessels are heated) the air doth issue forth with a strong and lasting violence. These are frequently used for the exciting and contracting of heat in the melting of glasses or metals. They may also be contrived to be serviceable for sundry other pleasant uses, as for the moving of sails in a chimney corner, the motion of which sails may be applied to the turning of a spit, or the like.

But there is a better invention to

De Varietate Rerum l. 12. c. 58.

this purpose mentioned in *Cardan*, whereby a spit may be turned (without the help of weights) by the motion of the air that ascends the Chimney; and it may be usefull for the roasting of many or great joints: for as the fire must be increased according to the quantity of meat, so the force of the instrument will be augmented proportionably to the fire. In which contrivance there are these conveniences above the Jacks of ordinary use.

1. It makes little or no noise in the motion.

2. It needs no winding up, but will constantly move of it self, while there is any fire to rarifie the air.

3. It is much cheaper then the other instruments that are commonly used to this purpose. There being required unto it onely a paire of sails, which must bee placed in that part of the chimnie where it begins to be straightned, and one wheel to the axis of which the spit line must be fastned, according to this following Diagram.

The

The motion of these sails may likewise be serviceable for sundry other purposes, besides the turning of a spit; for the chiming of bells or other musicall devices, and there cannot be any more pleasant contrivance for

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continuall & cheap muſick. It may be uſefull alſo for the reeling of yarn, the rocking of a cradle, with divers the like domeſtick occaſions. For (as was ſaid before) any conſtant motion being given, it is eaſie for an ingenious artificer to apply it unto various ſervices.

Theſe ſails will always move both day and night, if there is but any fire under them, and ſometimes though there bee none. For if the air without be much colder then that within the room, then muſt this (which is more warm and rarified) naturally aſcend through the chimney, to give place unto the more condenſed and heavy, which does uſually blow in at every chink or cranny, as experience ſhews.

Unto this kind of motion may be reduced all thoſe repreſentations of living creatures, whether birds, or beaſts, invented by *Cteſibius*, which were for the moſt part performed by the motion of air, being forced up either by *rarefaction*, with fire, or elſe by *compreſſion*, through the fall

of

of some heavier body, as water, which by possessing the place of the aire, did thereby drive it to seek for some other vent.

I cannot here omit (though it be al not altogether so pertinent) to mention that late ingenious invention of the winde-gun, which is charged by the forcible compression of air, being injected through a Syringe; the strife and distention of the imprisoned air serving by the help of little fals or shuts within, to stop and keep close the vents by which it was admitted. The force of it in the discharge is almost equall to our powder-guns. I have found upon frequent trials (saith *Mersennus*) that a leaden bullet shot from one of these gunnes against a stone wall, the space of 24 paces from it, will be beaten into a thinne plate. It would be a considerable addition to this experiment which the same Authour mentions a little after, whereby he will make the same charge of air to serve for the discharge of severall arrows or bullets after one another,

Phænomena pneumatica, prop. 32.

nother, by giving the air onely so much roome, as may immediately serve to impresse a violence in sending away the arrow or bullet, and then screwing it downe again to its former confinement, to fit it for another shooting. But against this there may be many considerable doubts, which I cannot stand to discusse.

Cap. II.

Of a sailing Chariot, that may without horses be driven on the land by the wind as ships are on the sea.

THe force of wind in the motion of sails may be applied also to the driving of a Chariot, by which a man may sail on the land as well as by a ship on the water. The labour of horses or other beasts, which are usually applied to this purpose, being artificially supplied by the strength of winds.

That such Chariots are commonly used in the Champion plains of *China*, is frequently affirmed by divers credible Authours. *Baterus* mentions that they have beene tried also in *Spaine*, though

De incremento Urbium l. 1. c. 10.

though with what success he doth not specifie. But above al other experimẽts to this purpose, that sailing Chariot at *Sceveling* in *Holland*, is more eminently remarkable. It was made by the direction of *Stephinus*, & is celebrated by many Authors. * *Walchius* affirms it to be of so great a swiftnesse for its motion, and yet of so great a capacity for its burden, *Vt in medio freto secundis ventis commissas naves, velocitate multis parasangis post se relinquat, & paucarũ horarum spatio, viginti aut triginta milliaria Germanica continuo cursu emetiatur, concredito sq; sibi plus minus vectores sex aut decẽ, in petitũ locũ trãsferat, facillime illius ad clavũ qui sedet nutu, quaqua versum minimo labore velis commissum, mirabile hoc continenti currus navigiũ dirigentis*. That it did far exceed the speed of any ship, though we should suppose it to be carried in the open sea with never so prosperous wind: and that in some few howers space it would convey 6 or 10 persons, 20 or 30 German miles, and all this with very little labour of him that sitteth at the Stearn, who

* *Fabularum decas, Fab. 9.*

who may easily guide the course of it as he pleaseth.

That eminent inquisitive man *Peireskius*, having travelled to *Sceveling* for the sight & experience of this chariot, would frequently after with much wonder mention the extream swiftnes of its motion. *Commemorare solebat stupore quo correptus fuerat cum vento translatus citatissimo non persentiscere tamen, nempe tã citus erat quã ventus.* Though the wind were in it self very swift and strong, yet to passengers in this Chariot, it would not be at all discernable, because they did goe with an equall swiftnesse to the wind it selfe. Men that ran before it seeming to goe backwards, things which seeme at a great distance being presently overtaken and left behind. In two howers space it would passe from *Sceveling* to *Putten*, which are distant from one another above 14 *Horaria millaria*, (saith the same Authour) that is more then two and forty miles.

Pet. Gassendus. Vita Peireskii, l. 2.

Grotius is very copious and elegant in the celebrating of this invention, and the

the Authour of it in divers Epigrams.

Ventivolam Tiphys deduxit in æquora navim,
Iupiter in ſtellas, ætheream que domum.
In terreſtre ſolum virtus Stevinia, nam nec
Tiphy tuum fuerat, nec Iovis iſtud opus.

Grotii Poemata, Ep. 19.

And in another place.

Impoſuit plauſtro vectantem carbaſa, malum
An potius navi, ſubdidit ille rotas?
--Scandit aquas navis curvus ſuit aere prono,
Et merito dicas hic volat, illa natat.

Ep. 5.

These relations did at the first seem unto me, (and perhaps they will so to others) somewhat strange & incredible. But upon farther enquiry I have heard them frequently attested from the particular eye-sight & experience of such eminent persons, whose names I dare not cite in a businesse of this nature, which in those parts is so very common, and little observed.

I have not met with any Authour who doth treat particularly concerning the manner of framing this Chariot, though *Grotius* mentions an elegant description of it in copper by one *Geynius*: and *Hondius* in one of his large maps of *Asia*, does give another conjecturall description of the like Chariots used in *China*.

Epig. 20, & 21.

The form of it is related to be very simple & plain, after this manner.

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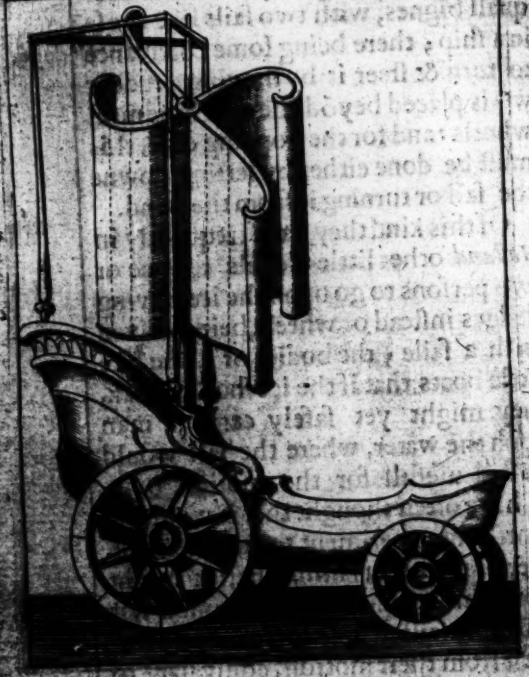
The body of it being ſomewhat like a boat, moving upon 4 wheels of an equall bignes, with two ſails like thoſe in a ſhip; there being ſome cõtrivance to turn & ſteer it by moving a rudder wch is placed beyõd the two hindmoſt wheels: and for the ſtopping of it, this muſt be done either by letting downe the ſail or turning it from the wind.

Of this kind they have frequently in *Holland* other little Veſſels for one or two perſons to go upon the ice, having ſledges inſtead of wheels, being driven with a ſaile, the bodies of them like little boats, that if the ice ſhould break, they might yet ſafely carry a man upon the water, where the ſail would be ſtill uſefull for the motion of it.

I have often thought that it would be worth the experiment to enquire, whether or no ſuch a ſailing chariot might not be more conveniently framed with movable ſails, whoſe force may be impreſt from their motion, equivalent to thoſe in a wind-mill. Their formoſt wheels (as in other Chariots) for the greater facility, being ſomewhat lower then the other, anſwerable to this figure.



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In which the sails are so contrived, that the wind from any Coast will have a force upon them to turn them about, and the motion of these sails must needs turn the wheels, and consequently carry on the Chariot it self to any place (though fully against the wind) whither it shall be directed.

The chief doubt will be, whether in such a contrivance every little ruggedness or unevenness of the ground, will not cause such a jolting of the Chariot as to hinder the motion of its sails. But this perhaps (if it should prove so) is capable of severall remedies.

I have often wondred, why none of our Gentry who live near great Plaines, and smooth Champions, have attempted any thing to this purpose. The expetiments of this kind being very pleasant, and not costly: what could be more delightfull or better husbandry, then to make use of the *wind* (which costs nothing, and eats nothing) instead of *horses*. This being very easie to be effected by little,

the convenience of whose habitations doth accommodate them for such experiments.

Cap. III.

Concerning the fixed Automata, *Clocks, Spheres, representing the heavenly motions: The severall excellencies that are most commendable in such kind of contrivances.*

THe second kind of αὐτόματα were described to be such Engines, as did receive a regular and lasting motion from something belonging to their own frame, whether weights, or springs, &c.

They are usually distinguished into αὐτόματα

- ἑάτα, fixed and stationary.
- ὑπάγοντα, moveable and transient.

1. The fixed are such as move only according to their severall parts, and not according to their whole frame; In which, though each wheel hath a distinct rotation, yet the whole doth still remain unmoved. The chiefest kind

kind of these are the clocks & watches in ordinary use, the framing of which is so commonly known by every Mechanick, that I shall not trouble the Reader with any explication of it. He that desires fuller satisfaction, may see them particularly described by * *Cardan*, † D. *Flood*, and others.

The first invention of these (saith *Pancirollus*) was taken from that experiment in the multiplication of wheels mentioned in *Vitruvius*, where he speaks of an instrument whereby a man may know how many miles or paces he doth goe in any space of time, whether or no he doe passe by water in a boat or ship, or by land in a chariot or coach: they have been contrived also into little pocket instruments, by which after a man hath walked a whole day together, he may easily know how many steps he hath taken. I forbear to enter upon a larger explication of these kind of Engines, because they are impertinent onto the chief business that

* *De Vacuo. Rer. l. 9. c. 47.*

† *Tract. 2. part. 7. l. 1. cap. 4. Repert. Tit. 10. Architect. l. 10. c. 14.*

I have proposed for this discourse. The Reader may see them more particularly described in the above cited place of *Vitruvius*, in * *Cardan*, † *Bessonius*, and others; I have here only mentioned them, as being the first occasion of the chiefest αὐτόματα that are now in use.

* *Subtil. l.* 18.
† *Theatrum instrumentorum. Wecker de secretis l.* 15. 6. 32.

Of the same kind with our clocks and watches (though perhaps more elaborate and subtle) was that sphere invented by *Archimedes*, which did represent the heavenly motions: the diurnall and annuall courses of the sun, the changes and aspects of the Moon, &c. This is frequently celebrated in the writings of the Ancients, particularly in that known *Epigram* of *Claudian*:

Mentioned by *Cicero, Tuscul. Quæst. l.* 1. *item De Nat. Deor. l.* 2.

Jupiter in parvo cum cerneret æthera vitro,
Risit, & ad superos talia dicta dedit;
Huccine mortalis progressa potentia curæ?
Jam meus in fragili luditur orbe labor.
Jura poli, rerumque fidem, legesque Deorum,
Ecce Syracusius transtulit arte senex.
*Inclusus variis famulatur * spiritus astris,*
Et vivum certis motibus urget opus.

* The secret force by which the motion was impressed.

Per-

Percurrit proprium mentitus Signifer annum;
Et simulata novo Cynthia mense redit.
Jamq; suum volvens audax industria mundum
Gaudet, & humanâ sidera mente regit.
Quid falso insontem tonitru Salmonea miror?
Æmula naturæ parva reperta manus.

Excellently Translated by *T. Randolph.*

Iove saw the heavens fram'd in a little *glasse*,
And laughing, to the gods these words did passe;
Comes then the power of mortall cares so far?
In brittle orbs my labours acted are.
The statures of the Poles, the faith of things,
The laws of Gods, this *Syracusian* brings
Hither by art: Spirits inclos'd attend
Their severall spheres, and with set motions bend
The living work: each year the feigned Sun,
Each month returns the counterfeited Moon.
And viewing now her world, bold industry
Grows proud, to know the heavens his subjects be.
Believe, *Salmoneus* hath false thunders thrown,
For a poor hand is natures rivall grown.

But that this Engine should be made of glasse, is scarce credible, *Lactantius* mentioning the relation of it, affirms it to consist of brasse, which is more likely. It may be the outside or case was glasse, and the frame it self of brasse. *Cœlius Rhodoginus*, speaking of the wondrous art in the contrivance

Instit. l. 2. c. 5.

Antiq. lect. l. 2. c. 16.

of this ſphere, breaks out into this quære. *Nonne igitur miraculorum omnium, maximum miraculum eſt homo?* He might have ſaid *Mathematicus*: and another to this purpoſe, *Sic manus ejus naturam, ut natura ipſa manum imitata putetur*. *Pappus* tels us, that *Archimedes* writ a Book *de Spharopœia*, cõcerning the manner of framing ſuch Engines, and after him *Poſidonius* compoſed another diſcourſe on the ſame ſubject, though now either the ignorance or the envy of time hath deprived us of both thoſe works. And yet the art it ſelf is not quite periſhed, for we read of divers the like contrivãces in theſe latter times. *Agrippa* affirms that he himſelf had ſeen ſuch a ſphere, & *Ramus* tels us how he beheld two of them in *Paris*, the one brought thither amongſt other ſpoiles from *Sicily*, and the other out of *Germany*. And it is commonly reported, that there is yet ſuch a ſphere at *Strasburg* in *Germany*. * *Rivaltus* relates how *Marinus Burgeſius* a *Norman* made two of them in *France* for the King.

And

Guid. Vbaldus præf. ad Mechan.

Collect. Mathem. Proam. ad l. 8.

De vanit. Sciẽt. c. 22. Schol. Mathem. l. 1. So Cardan too, l. 17. Monarch. in Mechan. Ariſt. Com. c. 1. Dr Hackwell, Apol. l. 2. c. 10. ſect. 2.

* *De vitâ Archimedis.*

And perhaps these latter (saith he) were more exact then the former, because the heavenly revolutions are now much better understood then before. And besides it is questionable, whether the use of steel springs was known in those ancient times, the application of which unto these kind of spheres, must needs be much more convenient then weights.

'Tis related also of the Consull *Boethius*, that amongst other Mathematicall contrivances, (for which he was famous) he made a sphere to represent the Suns motion, which was so much admired, and talked of in those times, that *Gundibaldus* King of *Burgundy*, did purposely send over Embassadors to *Theodoricus* the Emperour, with intreaties that he would be a means to procure one of these spheres from *Boethius*, the Emperor thinking hereby to make his kingdom more famous and terrible unto forain Nations, doth write an Epistle to *Boethius*, perswading him to send this instrument. *Quoties non sunt creduturi quod*

Cassiodor. Chron. Pet. Bertius praef. ad Consolat. Philos.

quod viderint? Quoties hanc veritatem luforia somnia quibus? Et quando fuerint à stupore conversi, non audebunt se æquales nobis dicere, apud quos sciunt sapientes talia cogitasse? So much were all these kind of inventions admired in those ruder & darker times: whereas the instruments that are now in use amongst us (though not so much extolled) yet doe altogether equall (if not exceed) the other, both in usefulnesse and subtilty. The chiefest of these former Engines receiving their motion from weighes, and not from springs, (which as I said before) are of later and more excellent invention.

Polyd. Virgil. de Invent. rerum l. 2 c. 5. Cardan Subtil. l. 17.

The particular circumstances for which the *Automata* of this kind are most eminent, may be reduced to these four.

1. The lastingnesse of their motion, without needing of any new supply; for which purpose there have been some watches contrived to continue without winding up for a week together, or longer.

2. The

2. The easinesse and simplicity of their composition; Art it self being but the facilitating and contracting of ordinary operations; therefore the more easie and compendious such inventions are, the more artificial should they be esteemed. And the addition of any such unnecessary parts, as may be supplied some other way, is a sure sign of unskilfulnesse and ignorance. Those antiquated engines that did consist of such a needlesse multitude of wheels, and springs, and screws, (like the old *hypothesis* of the heavens) may be compared to the notions of a confused knowledge, which are always full of perplexity and complications, and seldome in order; whereas the inventions of art are more regular, simple, and perspicuous; like the apprehensions of a distinct and thoroughly informed judgement. In this respect the manner of framing the ordinary *Automata*, hath been much bettered in these later times above the former, and shall hereafter perhaps be yet more advantaged.

These

These kind of experiments (like all other humane arts) receiving additions from every days experience.

To this purpose there is an invention consisting only of one hollow orb or wheel, whereby the howers may be as truly distinguished, as by any ordinary clock or watch. This wheel should be divided into severall cavities, through each of which successively either sand or water must be contrived to passe; the heavinesse of these bodies (being always in the ascending side of the wheel) must be counterpoised by a plummet that may be turned about the pulley on the axis: this plummet will leisurely descend, according as the sand by running out of one cavity into the next, doth make the severall parts of the wheel lighter or heavier, and so consequently there will be produced an equall and lasting motion, which may be easily applyed to the distinction of howers.

3. The multitude and variety of those services for which they may

be

be usefull. Unto this kind may we refer those watches, by which a man may tell not only the hower of the day, but the minute of the hower, the day of the month, the age and aspects of the Moone, &c. Of this nature likewise was that larum mentioned by *Walchius*, which though it were but two or three inches big, yet would both wake a man, and of it self light a candle for him at any set hower of the night. And those weights or springs which are of so great force as to turn a mill, (as some have been contrived) may be easily applyed to more various and difficult labours.

Fab. 9.

Ramel. fig. 130.

4. The littlenesse of their frame. *Nunquam ars magis quam in minimis vota est* (saith *Aquinas*.) The smalnesse of the Engine doth much commend the skill of the artificer; to this purpose there have been watches contrived in the form and quantity of a Jewell for the ear, where the striking of the minutes may constantly whisper unto us, how our lives doe slide away

Iacks no bigger then a Walnut to turn any joint of meat.

away by a swift succession. *Cardan* tels us of a Smith who made a watch in the Jewell of a ring, to be worn on the finger, which did shew the howers, (*non solum sagitta, sed ictu*) not only by the hand, but by the finger too (as I may say) by pricking it every hower.

De subtil. l. 2. item l. 17.

CAP. IV.

Of the moveable and Gradient Automata, representing the motions of living creatures, various sounds, of birds, or beasts, and some of them articulate.

THus much of those Automata, which were said to be fixed and stationary.

The other kind to be inquired after, are those that are moveable and transient, which are described to be such engines as move not only according to their severall parts, but also according to their whole frames. These are again distinguishable into two sorts:

1. *Gra-*

1. *Gradient.*
2. *Volant.*

1. The *Gradient* or *ambulatory*, are such as require some *basis* or bottome to uphold them in their motions. Such were those strange inventions (commonly attributed to *Dedalus*) of self-moving statues, which (unlesse they were violently detained) would of themselves run away. * *Aristotle* affirms that *Dedalus* did this by putting quick-silver into them. But this would have been too grosse a way for so excellent an artificer, it is more likely that he did it with wheels & weights. Of this kind likewise were *Vulcans Tripodes*, celebrated by *Homer*, that were made to move up and down the house, and fight with one another. He might as well have contrived them into Journey-men statues, each of which with a hammer in his hand should have worked at the forge.

Plato in Menone. Arist. Polit. l. 1. c. 3.

* *De Anima l. 1. c. 3.*

Iliad. 18.

There have been also chariots driven by the force of a spring contrived within them. *De Varietate rerum l. 12. c. 58.*

But amongst these fighting images, that in *Cardan* may deserve a mention, which holding in its hand a golden apple, beautified with many costly Jewels;

Jewels; if any man offered to take it, the ſtatue preſently ſhot him to death. The touching of this apple ſerving to diſcharge ſeverall ſhort bows, or other the like inſtruments that were ſecretly couched within the body of the image. By ſuch a treachery was King *Chennetus* murdered (as *Boethius* relates.

It is ſo common an experiment in theſe times to repreſent the perſons and actions of any ſtory by ſuch ſelf-moving images, that I ſhall not need to explain the manner how the wheels and ſprings are contrived within them.

Fab.9. There have been other inventions to move on the water. *Navigium ſponte mobile, ac ſui remigii autorem, faciam nullo negotio,* ſaith *Scaliger, Exer.326.*

Amongſt theſe gradient *Automata*, that iron ſpider mentioned in *Walchius*, is more eſpecially remarkable, which being but of an ordinary bigneſſe, beſides the outward ſimilitude, (wch was very exact) had the ſame kind of motions with a living ſpider, and did creep up and down as if it had been alive. It muſt needs argue a wonderfull art, and accurateneſſe, to contrive all the inſtruments requiſite for ſuch

a

a motion in ſo ſmall a frame.

There have been alſo other motions contrived from Magneticall qualities, which will ſhew the more wonderful, becauſe there is no apparent reaſon of their motion, there being not the leaſt contiguity or dependence upon any other body that may occaſion it; but it is all one as if they ſhould move up and down in the open air. Get a glaſſe ſphere, fill it with ſuch liquors as may be clear of the ſame colour, immixable, ſuch as are oyl of tartar, and ſpirit of wine: In which, it is eaſie ſo to poiſe a little globe or other ſtatue, that it ſhall ſwim in the center. Under this glaſſe ſphere, there ſhould be a loadſtone concealed, by the motion of which, this ſtatue (having a needle touched within it) will move up and down, and may be contrived to ſhew the hower or ſign. See ſeverall inventions of this kinde in *Kircher de arte Magnetica, l.* 2.

There have been ſome artificiall images, which beſides their ſeverall poſtures in walking up and downe, have

have been made also to give severall sounds, whether of birds, as Larks, Cuckoes, &c. or beasts, as Hares, Foxes. The voices of which creatures shall be rendred as clearly and distinctly, by these artificiall images, as they are by those naturall living bodies, which they represent.

There have been some inventions also which have been able for the utterance of articulate sounds, as the speaking of certain words. Such are some of the Ægyptian idols related to be. Such was the brazen head made by Friar *Bacon*, and that statue in the framing of which *Albertus Magnus* bestowed thirty years, broken by *Aquinas*, who came to see it, purposely that he might boast, how in one minute he had ruined the labour of so many years.

Cæl. Rhod. lect. Ant. l. 2. c. 17. Maiolus Colloq.

Now the ground and reason how these sounds were contrived, may be worth our inquiry.

First then, for those of birds or beasts, they were made from such pipes or cals, as may expresse the severall

verall tones of those creatures which are represented: these cals are so commonly known and used, that they need not any further explication.

But now about articulate sounds there is much greater difficulty. *Walchius* thinks it possible entirely to preserve the voice, or any words spoken, in a hollow trunk, or pipe, and that this pipe being rightly opened, the words will come out of it in the same order wherein they were spoken. Somewhat like that cold Countrey, where the peoples discourse doth freeze in the air all winter, and may be heard the next Summer, or at a great thaw. But this conjecture will need no refutation. *Fab. 9.*

The more substantiall way for such a discovery, is by marking how nature her self doth imploy the severall instruments of speech, the tongue, lips, throat, teeth, &c. To this purpose the Hebrews have assigned each letter unto its proper instrument. And besides, we should observe what inarticulate sounds doe resemble any of

the particular letters. Thus we may note the trembling of water to be like the letter *L*, the quenching of hot things to the letters *Z*, the sound of strings, unto the letter *Ng*, the jirking of a switch the letter *Q*, &c. By an exact observation of these particulars, it is (perhaps) possible to make a statue speak some words.

Bacon Nat. hist exper. 139. 200.

Cap. V.

Concerning the possibility of framing an Ark for submarine Navigations. The difficulties and conveniences of such a contrivance.

IT will not be altogether impertinent unto the discourse of these gradient *Automata*, to mention what *Mersennus* doth so largely and pleasantly descant upon, concerning the making of a ship, wherein men may safely swim under water.

Tract de Magnetis proprietatibus.

That such a contrivance is feasible and may be effected, is beyond all question, because it hath been already

dy experimented here in *England* by *Cornelius Dreble*, but how to improve it unto publike use and advantage, so as to be serviceable for remote voyages, the carrying of any considerable number of men, with provisions and commodities, would be of such excellent use as may deserve some further inquiry.

Concerning which there are two things chiefly considerable:

The { many difficulties with their remedies. / great conveniences.

1. The difficulties are generally reducible to these three heads:

1. The letting out, or receiving in any thing, as there shall be occasion without the admission of water. If it have not such a convenience, these kind of voyages must needs be very dangerous and uncomfortable, both by reason of many noisome offensive things, which should be thrust out, and many other needfull things which should be received in. Now herein will consist the difficulty, how to con-

trive the opening of this veſſell ſo, that any thing may be put in or out, and yet the water not ruſh into it with much violence, as it doth uſually in the leak of a ſhip.

In which caſe this may be a proper remedy; let there be certain leather bags made of ſeverall bigneſſes, which for the *matter* of them ſhould be both *tractable* for the uſe and managing of them, and *ſtrong* to keep out the water, for the *figure* of them being long and open at both ends. Anſwerable to theſe, let there be divers windows, or open places in the frame of the ſhip, round the ſides of which one end of theſe bags may be fixed, the other end coming within the ſhip being to open and ſhut as a purſe. Now if we ſuppoſe this bag thus faſtned, to be tyed cloſe about towards the window, then any thing that is to be ſent out, may be ſafely put into that end within the ſhip, which being again cloſe ſhut, and the other end looſened, the thing may be ſafely ſent out without the admiſſion of any water.

So

So again, when any thing is to be taken in, it muſt be firſt received into that part of the bag towards the window, which being (after the thing is within it) cloſe tyed about, the other end may then be ſafely opened. It is eaſie to conceive, how by this means any thing or perſon may be ſent out, or received in, as there ſhall be occaſion, how the water, which will perhaps by degrees leak into ſeveral parts, may be emptyed out again, with divers the like advantages. Though if there ſhould be any leak at the bottome of this Veſſell, yet very little water would get in, becauſe no air could get out.

2. The ſecond difficuly in ſuch an Ark will be the *motion* or *fixing* of it according to occaſion; The *directing* of it to ſeverall places, as the voyage ſhall be deſigned, without which, it would be very uſeleſſe, if it were to remain only in one place, or were to remove only blindfold, without any certain direction; And the contrivance of this may ſeem very diffi-

cult, because these submarine Navigators will want the usuall advantages of winds and tides for motion, and the sight of the heavens for direction.

But these difficulties may be thus remedied; As for the *progressive* motion of it, this may be effected by the help of severall Oars, which in the outward ends of them, shall be like the fins of a fish to contract and dilate. The passage where they are admitted into the ship being tyed about with such leather bags (as were mentioned before) to keep out the water. It will not be convenient perhaps that the motion in these voyages should be very swift, because of those observations and discoveries to be made at the bottome of the sea, which in a little space may abundantly recompense the slowness of its progresse.

If this Ark be so ballast as to be of equall weight with the like magnitude of water, it will then be easily movable in any part of it.

As for the *ascent* of it, this may be easily contrived, if there be some great weight

weight at the bottome of the ship (being part of its ballast) which by some cord within may be loosened from it; As this weight is let lower, so will the ship ascend from it (if need be) to the very surface of the water; and again, as it is pulled close to the ship, so will it *descend*.

For *direction* of this Ark, the Mariners needle may be usefull in respect of the *latitude* of places, and the course of this ship being more regular then others, by reason it is not subject to Tempests or unequall winds, may more certainly guide them in judging of the *longitude* of places.

3. But the greatest difficulty of all will be this, how the air may bee supplyed for respiration: How constant fires may be kept in it for light and the dressing of food, how those vicissitudes of rarefaction and condensation may be maintained.

It is observed, that a barrell or cap, whose cavity will contain eight cubicall feet of air, will not serve a Urinator or Diver for respiration, a-

bove one quarter of an hower; the breath which is often ſucked in and out, being ſo corrupted by the mixture of vapours, that nature rejects it as unſerviceable. Now in an hower a man will need at leaſt 360 reſpirations, betwixt every one of which there ſhall be 10 ſecond minutes, and conſequently a great change and ſupply of air will be neceſſary for many perſons, and any long ſpace.

And ſo likewiſe for the keeping of fire; a cloſe Veſſell containing 10 cubicall feet of air, will not ſuffer a wax candle of an ounce to burn in it above an hower before it be ſuffocated, though this proportion (ſaith *Merſennus*) doth not equally increaſe for ſeverall lights, becauſe four flames of an equall magnitude will be kept alive the ſpace of 16 ſecond minutes, though one of theſe flames alone in the ſame Veſſell will not laſt above 25, or at moſt 30 ſeconds, which may be eaſily tryed in large glaſſe bottles, having wax candles lighted in them, and with their mouths inverted in water.

For

For the resolution of this difficulty, though I will not say that a man may by custome (which in other things doth produce such strange incredible effects) be inabled to live in the open water as the fishes doe, the inspiration and expiration of water serving instead of air, this being usuall with many fishes that have lungs; yet it is certain that long use and custome may strengthen men against many such inconveniences of this kind, which to unexperienced persons may prove very hazzardous: and so it will not perhaps be unto these so necessary, to have the air for breathing so pure and defecated as is required for others.

But further there are in this case these three things considerable.

1. That the Vessell it self should be of a large capacity, that as the air in it is corrupted in one part, so it may be purified and renued in the other: or if the meer refrigeration of the air would fit it for breathing, this might be somewhat helped with bellows,

bellows, which would cool it by motion.

2. It is not altogether improbable, that the lamps or fires in the middle of it, like the reflected beams in the first Region, rarefying the air, and the circumambient coldnesse towards the sides of the Vessell, like the second Region, cooling and condensing of it, would make such a vicissitude and change of air, as might fit it for all its proper uses.

Harmon. l.4. prop.6. Music. 5.

3. Or if neither of these conjectures will help, yet *Mersennus* tels us in another place, that there is in *France* one *Barriens* a Diver, who hath lately found out another art, whereby a man might easily continue under water for six howers together, and whereas ten cubicall feet of air will not serve another Diver to breath in for half an hower, he by the help of a cavity, not above one or two foot at most, will have breath enough for six howers, and a lanthorn scarce above the usuall size to keep a candle burning as long as a man please, which

(it

(if it be true, and were commonly known) might be a sufficient help against this greatest difficulty.

As for the many advantages and conveniences of such a contrivance, it is not easie to recite them.

1. 'Tis *private*; a man may thus goe to any coast of the world invisibly, without being discovered or prevented in his journey.

2. 'Tis *safe*; from the uncertainty of *Tides*, and the violence of *Tempests*, which doe never move the sea above five or six paces deep. From *Pirates* and *Robbers* which do so infest other voyages; From ice and great frosts, which doe so much endanger the passages towards the Poles.

3. It may be of very great advantage against a Navy of enemies, who by this means may be undermined in the water and blown up.

4. It may be of speciall use for the relief of any place that is besieged by water, to convay unto them invisible supplies: and so likewise for the surprisall of any place that is accessible by water.

5. It

5. It may be of unſpeakle benefit for ſubmarine experiments and diſcoveries: as

The ſeverall proportions of ſwiftneſſe betwixt the aſcent of a bladder, cork, or any other light ſubſtance in compariſon to the deſcent of ſtones or lead. The deep caverns and ſubterraneous paſſages where the ſea-water in the courſe of its circulation, doth vent it ſelf into other places, and the like. The nature and kinds of fiſhes, the ſeverall arts of catching them, by alluring them with lights, by placing divers nets about the ſides of this Veſſell, ſhooting the greater ſort of them with guns, which may be put out of the ſhip by the help of ſuch bags as were mentioned before, with divers the like artifices and treacheries, which may be more ſucceſſively practiſed by ſuch who live ſo familiarly together. Theſe fiſh may ſerve not only for food, but for fewell likewiſe, in reſpect of that oyl which may be extracted from them; the way of dreſſing meat by lamps, being

ing in many respects the most convenient for such a voyage.

The many fresh springs that may probably be met with in the bottome of the sea, will serve for the supply of drink and other occasions.

But above all, the discovery of submarine treasures is more especially considerable, not only in regard of what hath been drowned by racks, but the severall precious things that grow there, as Pearl, Corall, Mines, with innumerable other things of great value, which may be much more easily found out, and fetcht up by the help of this, then by any other usually way of the Urinators.

To which purpose, this great Vessell may have some lesser cabines tyed about it, at various distances, wherein severall persons as Scouts, may be lodged for the taking of observations, according as the Admirall shall direct them. Some of them being frequently sent up to the surface of the water, as there shall be occasion.

All

All kind of arts and manufactures may be exerciſed in this Veſſell. The obſervations made by it, may bee both written, and (if need were) printed here likewiſe. Severall Colonies may thus inhabit, having their children born and bred up without the knowledge of land, who could not chuſe but be amazed with ſtrange conceits upon the diſcovery of this upper world.

I am not able to judge what other advantages there may be ſuggeſted, or whether experiment would fully anſwer to theſe notionall conjectures. But however, becauſe the invention did unto me ſeem ingenious and new, being not impertinent to the preſent enquiry, therefore I thought it might be worth the mentioning.

Cap.

Cap. VI.

Of the volant Automata, Archytas *his Dove, and* Regiomontanus *his Eagle. The possibility and great usefulnesse of such inventions.*

THe *volant* or flying *Automata* are such Mechanicall contrivances, as have a self-motion, whereby they are carried aloft in the open air, like the flight of Birds. Such was that wooden Dove made by *Archytas*, a Citizen of *Tarentum*, and one of *Plato's* acquaintance. And that wooden Eagle framed by *Regiomontanus* at *Noremberg*, which by way of triumph, did fly out of the City to meet *Charles* the fift. This later Author is also reported to have made an iron fly, *Quæ ex artificis manu egressa, convivas circumvolitavit, tandemque velut defessa in Domini manus reversa est*, which when he invited any of his friends, would fly to each of them round the table, and at length (as being weary) return unto its Master.

Diog. Laer. l. 8. Pet. Crinitus de honest. disciplin. l. 17. c. 12.

Remus Schol. Mathem. l. 1.

Dubartas 6 days 1 W. l. Dee Preface to Euclid.

Cardan

De Variet. rerum lib. 12. c. 58.

Cardan seems to doubt the possibility of any such contrivance; his reason is, because the instruments of it must be firm and strong, and consequently they will be too heavy to be carried by their own force; but yet (saith he) if it be a little helped in the first rising, and if there be any wind to assist it in the flight, then there is nothing to hinder, but that such motions may be possible. So that he doth in effect grant as much as may be sufficient for the truth and credit of those ancient relations; and to distrust them without a stronger argument, must needs argue a blind and perverse incredulity. As for his objection concerning the heavinesse of the materials in such an invention, it may be answered that it is easie to contrive such springs and other instruments, whose strength shall much exceed their heavinesse. Nor can he shew any cause why these Mechanicall motions may not be as strong, (though not so lasting) as the naturall strength of living creatures.

Scaliger

Scaliger conceives the framing of such volant *Automata*, to be very easie. *Volantis columbæ machinulam, cujus autorem Archytam tradunt, vel facillime profiteri audeo.* Those ancient motions were thought to be contrived by the force of some included air: So *Gellius*, *Ita erat scilicet libramentis suspensum, & auræ spiritus inclusâ atque occultâ consitum, &c.* As if there had been some lamp, or other fire within it, which might produce such a forcible rarefaction, as should give a motion to the whole frame.

But this may be better performed by the strength of some such spring as is commonly used in watches; this spring may bee applyed unto one wheel, which shall give an equall motion to both the wings; these wings having unto each of them another smaller spring by which they may be contracted and lifted up: So that being forcibly depressed by the strength of the great and stronger spring, and lifted up again by the other two. According to this suppo-

Subtil. Exercit. 326.

Noct. Attic. l. 10. *cap.* 12. where he thinks it so strange an invention that he styles *Res abhorrens à fide. Athan. Kircher de Magnete l.* 2. *par.* 4. Proem: doth promise a large discourse concerning these kind of inventions in another Treatise which he styles *Oedipus Aegyptiacus.*

sition, it is easie to conceive how the motion of flight may be performed and continued.

The wings may be made either of *several substances joyned*, like the feathers in ordinary fowl, as *Dædalus* is feigned to contrive them, according to that in the Poet,

Ovid. Metam. l. 8.

--Ignotas animum dimittit in artes,
Naturamque novat, nam ponit in ordine pennas
A minimo cœptas longam breviore sequente,
Vt clivo crevisse putes, &c.

Or else of *one continuate substance*, like those of Bats. In framing of both which, the best guidance is to follow (as near as may be) the direction of nature; this being but an imitation of a naturall work. Now in both these, the strength of each part is proportioned to the force of its imployment. But nothing in this kind can be perfectly determined without a particular triall.

Though the composing of such motions may be a sufficient reward to any ones industry in the searching af-

after them, as being in themselves of excellent curiosity; yet there are some other inventions depend upon them of more generall benefit and greater importance. For if there be any such artificiall contrivances that can flye in the air, (as is evident from the former relations, together with the grounds here specified, and I doubt not, may bee easily effected by a diligent and ingenious artificer) then it will clearly follow, that it is possible also for a man to fly himself: It being easie from the same grounds to frame an instrument, wherein any one may sit, and give such a motion unto it, as shall convey him aloft through the air. Then which there is not any imaginable invention that could prove of greater benefit to the world, or glory to the Author. And therefore it may justly deserve their enquiry, who have both leisure and means for such experiments.

But in these practicall studies, unlesse a man be able to goe to the tryall of things; he will perform but

little. In such matters,

Horace. *-Studium sine divite venâ,*

(as the Poet saith) a generall speculation, without particular experiment, may conjecture at many things, but can certainly effect nothing. And therefore I shall only propose unto the world, the Theory and generall grounds that may conduce to the easie and more perfect discovery of the subject in question, for the incouragement of those that have both minds and means for such experiments. This same Scholars fate,

Res angusta domi, and

--curta supellex

is that which hinders the promoting of learning in sundry particulars, and robs the world of many excellent inventions. We read of *Aristotle*, that he was allowed by his pupill *Alexander* 800 talents a year, for the payment of Fishers, Fowlers, and Hunters, who were to bring him in severall creatures, that so by his particular experience of their parts and dispositions, he might be more fitly prepared

pared to write of their natures. The reason why the world hath not many *Aristotles* is, because it hath so few *Alexanders*.

Amongst other impediments of any strange invention or attempts, it is none of the meanest discouragements, that they are so generally derided by common opinion, being esteemed only as the dreams of a melancholy & distempered fancy. *Eusebius* speaking with what necessity every thing is confined by the laws of nature, and the decrees of providence, so that nothing can goe out of that way, unto which naturally it is designed; as a fish cannot reside on the land, nor a man in the water, or aloft in the air, infers, that therefore none will venture upon any such vain attempt, as passing in the air, ἢ μελαγχολίας νοσήματα ἂν πρεπόσαι, unlesse his brain be a little crazed with the humour of melancholy; whereupon he advises that we should not in any particular endevour to transgresse the bounds of nature, οὐδὲ ἄπτερον ἔχοντα τὸ σῶμα, τὰ τῶν πτηνῶν

Contra Hierocl. confut. l. 1.

πτηνῶν ἐπιτηδεύειν, and since we are naturally destitute of wings, not to imitate the flight of Birds. That saying of the Poet,

Virgil. Aeneid. l. 6.

Demens qui nimbos & non imitabile fulmen, &c.

hath been an old censure applyed unto such as ventured upon any strange or incredible attempt.

Hence may we conceive the reason, why there is so little intimation in the writings of antiquity, concerning the possibility of any such invention. The Ancients durst not so much as mention the art of flying, but in a fable.

Dædalus, ut fama est, fugiens Minoia regna,
Præpetibus pennis ausus se credere cœlo,
Insuetum per iter gelidas enavit ad arctos, &c.

It was the custome of those former ages, in their overmuch gratitude, to advance the first Authours of any usefull discovery, amongst the number of their gods. And *Dædalus* being so famous amongst them for

sundry

ſundry Mechanicall inventions (eſpecially the ſails of ſhips) though they did not for theſe place him in the heavens, yet they have promoted him as near as they could, feigning him to fly aloft in the air, when as he did but fly in a ſwift ſhip; as *Diodorus* relates the Hiſtoricall truth, on which that fiction is grounded.

So Euſebius too.

Cap. VII.

Concerning the Art of flying. The ſeverall ways whereby this hath been or may be attempted.

I Have formerly in two other * Diſcourſes mentioned the poſſibility of this art of flying, and intimated a further inquiry into it, which is a kind of engagement to ſome fuller diſquiſitions and conjectures to that purpoſe.

* World in the Moon, c. 14. Mercury, or the ſecret and ſwift Meſſenger, c. 4.

There are four ſeverall ways whereby this flying in the air, hath beene or may be attempted. Two of them by the ſtrength of other things, and

two of them by our owne ſtrength.

1. By ſpirits or Angels.

2. By the help of fowls.

3. By wings faſtned immediately to the body.

4. By a flying chariot.

1. For the firſt, we read of divers that have paſſed ſwiftly in the air, by the help of ſpirits and Angels, whether good Angels, as * *Elias* was carried unto heaven in a fiery chariot: as † *Philip* was conveyed to *Azotus*, and *Habbacuck* from Jewry to Babylon, and back again immediately: Or by evill Angels, as our Saviour was carried by the Devill to the top of a high mountain, and to the pinacle of the Temple. Thus witches are commonly related to paſſe unto their uſuall meetings in ſome remote place; and as they doe ſell windes unto Mariners, ſo likewiſe are they ſometimes hired to carry men ſpeedily through the open air. *Acoſta* affirms that ſuch kind of paſſages are uſuall amongſt divers Sorcerers with the Indians at this day.

Zanch. de oper. pars 2. l. 4.

* 2 Kings 2. 11.

† Acts 8. 39. Dan. Apoc 39.

Luke 4.

Erastus de Lamiis.

Hiſt. Ind. l. 5. c. 26.

So

So *Kepler* in his Astronomicall dream, doth fancy a witch to be conveyed unto the Moon by her Familiar.

Simon Magus was so eminent for miraculous sorceries, that all the people in *Samaria* from the least to the greatest, did esteem him *as the great power of God.* And so famous was he at *Rome*, that the Emperour erected a statue to him with this inscription, *Simoni Deo Sancto.* 'Tis storied of this Magician, that having challenged Saint *Peter* to doe miracles with him, he attempted to fly from the Capitoll to the Aventine hill. But when he was in the midst of the way, Saint *Peters* prayers did overcome his sorceries, and violently bring him to the ground, in which fall having broke his thigh, within a while after he died.

Acts 8. 10.

Hegesip. l. 3 c. 2.

Pol. Virgil. de Inven. Rerum. l. 8. c. 3.

Pet. Crinitus de Honest. Disciplin. l. 8. c. 1. mistrusts this relation as fabulous, *Non enim Lucas hoc omisisset.*

But none of all these relations may conduce to the discovery of this experiment, as it is here enquired after, upon *natural* & *artificial* grounds.

2. There are others who have con-

conjectured a possibility of being conveyed through the air by the help of fowls; to which purpose that fiction of the *Ganza's*, is the most pleasant and probable. They are supposed to be great fowl of a strong lasting flight, and easily tamable. Divers of which may be so brought up as to joyn together in carrying the weight of a man, so as each of them shall partake his proportionable share of the burden; and the person that is carried may by certain reins direct and steer them in their courses. However this may seem a strange proposall, yet it is not certainly more improbable, then many other arts, wherein the industry of ingenious men hath instructed these brute creatures. And I am very confident, that one whose genius doth enable him for such kind of experiments upon leisure, and the advantage of such helps as are requisite for various and frequent trials, might effect some strange thing by this kind of enquiry.

'Tis reported as a custome amongst the

the *Leucadians*, that they were wont upon a superstition to precipitate a man from some high cliffe into the sea, tying about him with strings at some distance, many great fowls, and fixing unto his body divers feathers spread, to break the fall; which (saith the learned *Bacon*, if it were diligently and exactly contrived) would be able to hold up, and carry any proportionable weight; and therefore he advises others to think further upon this experiment, as giving some light to the invention of the art of flying.

Nat. hist. experim. 886.

3. 'Tis the more obvious and common opinion that this may be effected by wings fastned immediately to the body, this coming neerest to the imitation of nature, which should be observed in such attempts as these. This is that way which *Fredericus Hermannus* in his little discourse *de Arte volandi*, doth onely mention and insist upon. And if we may trust credible story, it hath been frequently attempted not without some successe.

So the ancient British Blaudus.

'Tis

Eynsham Burgravus in Panoplia Physico-Vulcania. Sturmius in Lat: linguæ resolut.

'Tis related of a certaine Englisn Munk called *Elmerus*, about the Confessors time, that he did by such wings fly from a Tower above a furlong; and so another from Saint *Marks* steeple in *Venice*; another at *Norinberge*; and *Busbequius* speaks of a Turk in *Constantinople*, who attempted something this way. M. *Burton* mentioning this quotation, doth beleeve that some new-fangled wit ('tis his cynicall phrase) will some time or other find out this art. Though the truth is, most of these Artists did unfortunately miscarry by falling down and breaking their arms or legs, yet that may be imputed to their want of experience, and too much fear, which must needs possesse men in such dangerous and strange attempts. Those things that seem very difficult and fearfull at the first, may grow very facil after frequent triall and exercise. And therefore he that would effect any thing in this kind, must be brought up to the constant practise of it from his youth. Trying

Melancholy, Par. 2. Sect. 1. Mem. 3.

ing first onely to use his wings in running on the ground, as an Estrich or tame Geese will doe, touching the earth with his toes; and so by degrees learn to rise higher, till hee shall attain unto skill and confidence. I have heard it from credible testimony, that one of our own Nation hath proceeded so far in this experiment, that he was able by the help of wings in such a running pace to step constantly ten yards at a time.

It is not more incredible that frequent practise and custome should inable a man for this, then for many other things which we see confirmed by experience. What strange agility & activenesse doe our common tumblers & dancers on the rope attain to by cõtinuall exercise? 'Tis related of certain Indians, that they are able when a horse is running in his full career, to stand upright on his back, to turn themselves round, to leap down, gathering up any thing from the ground, & immediatly to leap up again, to shoot exactly at any mark, the horse not intermitting

Maffeus Hist. Ind. l. 1.

mitting his course. And so upon two horses together, the man setting one of his feet upon each of them. These things may seem impossible to others, and it would be very dangerous for any one to attempt them, who hath not first gradually attained to these arts, by long practise and triall; and why may not such practise inable him as well for this other experiment, as for these things?

There are others who have invented ways to walk upon the water, as regularly and firmly as upon the land. There are some so accustomed to this element, that it hath been almost as naturall to them, as to the fish; men that could remain for above an hower together under water. *Pontanus* mentions one who could swim above a hundred miles together, from one shore to another, with great speed, and at all times of the year. And it is storied of a certain young man, a *Sicilian* by birth, and a *Diver* by profession, who had so continually used himself to the water, that he could

Treatise of custome.

not

not enjoy his health out of it. If at any time he ſtaid with his friends on the land, he ſhould be ſo tormented with a pain in his ſtomack, that he was forced for his health to returne back again to ſea; wherein he kept his uſuall reſidence, and when hee ſaw any ſhips, his cuſtome was to ſwim to them for relief, which kind of life he continued till he was an old man, and dyed.

I mention theſe things to ſhew the great power of practiſe and cuſtome, which might more probably ſucceed in this experiment of flying (if it were but regularly attempted) then in ſuch ſtrange effects as theſe.

It is a uſuall practiſe in theſe times, for our *Funambulones*, or Dancers on the Rope, to attempt ſomewhat like to flying, when they will with their heads forwards ſlide downe a long cord extended; being faſtned at one end on the top of ſome high Tower, and the other at ſome diſtance on the ground, with wings fixed to their ſhoulders, by the ſhaking of which they

they will break the force of their descent. It would seem that some attempts of this kind were usuall amongst the *Romanes*. To which that expression in * *Salvian* may referre, where amongst other publike shewes of the Theater, he mentions the *Petaminarii*: which word (saith *Jo: Brassicanus*) is scarce to be found in any other Authour, being not mentioned either in *Julius Pollux*, or *Polician*. 'Tis probably derived from the Greek word πέτομαι, which signifies to fly, and may refer to such kind of Rope-dancers.

* *De guber. Dei. l. 6.*

Annot. in Salvi.

But now because the arms extended, are but weak and easily wearied, therfore the motions by them are like to be but short and slow, answerable it may be to the flight of such domestick fowl as are most conversant on the ground, which of themselves we see are quickly weary, and therefore much more would the arm of a man, as being not naturally designed to such a motion.

It were therefore worth the inqui-

ry

ry to consider whether this might not be more probably effected by the labour of the feet, which are naturally more strong and indefatigable: In which contrivance the wings should come down from the shoulders on each side as in the other, but the motion of them should be from the legs, being thrust out and drawn in again one after another, so as each leg should move both wings, by which means a man should (as it were) walk or climbe up into the air: and then the hands and arms might be at leisure to help and direct the motion, or for any other service proportionable to their strength. Which conjecture is not without good probability, and some speciall advantages above the other.

4. But the fourth and last way seems unto me altogether as probable, and much more usefull then any of the rest. And that is by a flying chariot, which may be so contrived as to carry a man within it; & though the strength of a spring might per-

haps be ſerviceable for the motion of this engine, yet it were better to have it aſſiſted by the labour of ſome intelligent mover as the heavenly orbs are ſuppoſed to be turned. And therefore if it were made big enough to carry ſundry perſons together, then each of them in their ſeverall turns might ſucceſſively labour in the cauſing of this motion; which thereby would be much more conſtant and laſting, then it could otherwiſe be, if it did wholly depend on the ſtrength of the ſame perſon. This contrivance being as much to be preferred before any of the other, as ſwimming in a ſhip before ſwimming in the water.

Cap. VIII.

A reſolution of the two chief difficulties that ſeem to oppoſe the poſſibility of a flying Chariot.

THe chief difficulties againſt the poſſibility of any ſuch contrivance may be fully removed in the reſolu-

tion

tion of these two *Quares*.

1. Whether an engine of such capacity and weight, may be supported by so thin and light a body as the air?

2. Whether the strength of the persons within it, may be sufficient for the motion of it?

1. Concerning the first; when *Callias* was required by the men of *Rhodes*, to take up that great *Helepolis*, brought against them by *Demetrius*, (as he had done before unto some lesse which hee himselfe had made.) He answered that it could not be done. *Nonnulla enim sunt quæ in exemplaribus videntur similia, cum autem crescere cœperunt, dilabuntur*. Because those things that appear probable in lesser models, when they are increased to a greater proportion, doe thereby exceed the power of art. For example, though a man may make an instrument to bore a hole, an inch wide, or half an inch, and so lesse, yet to bore a hole of a foot wide, or two foot, is not so much as to bee

Vitruvius Archit. l. 10 c. 22.

So *Ramus Schol. Mathem. l.* 1.

thought of. Thus, though the air may be able to uphold ſome leſſer bodies, as thoſe of birds, yet when the quantity of them is increaſed to any great extenſion, it may juſtly be doubted, whether they will not exceed the proportion that is naturally required unto ſuch kind of bodies.

To this I anſwer, that the engine can never be too big or too heavy, if the ſpace which it poſſeſſes in the air, and the motive faculty in the inſtrument be anſwerable to its weight. That ſaying of *Callias* was but a groundleſſe ſhift and evaſion, wherby hee did endeavour to palliate his own ignorance and diſability. The utmoſt truth which ſeems to be implyed in it, is this: That there may be ſome bodies of ſo great a bigneſſe, & gravity, that it is very difficult to apply ſo much force unto any particular inſtrument, as ſhall be able to move them.

Againſt the example it may be affirmed and eaſily proved, that it is equally poſſible to bore a hole of any bigneſſe,

bigneſſe, as well great as little, if we ſuppoſe the inſtrument, & the ſtrength and the application of this ſtrength to be proportionable; But becauſe of the difficulty of theſe concurrent circumſtances in thoſe greater and more unuſuall operations, therefore doe they falſly ſeem to be abſolutely impoſſible.

So that the chief inference from this argument and example, doth imply onely thus much, that it is very difficult to contrive any ſuch motive power, as ſhall be anſwerable to the greatneſſe and weight of ſuch an inſtrument as is here diſcourſed of, which doth not at all impair the truth to be maintained; For if the poſſibility of ſuch a motion be yeelded, we need not make any ſcruple of granting the difficultie of it; It is this muſt adde a glory to the invention, and yet this will not perhaps ſeem ſo very difficult to any one who hath but diligently obſerved the flight of ſome other birds, particularly of a Kite, how he will ſwim up and down

in the air, sometimes at a great height, and presently again lower, guiding himself by his train, with his wings extended without any sensible motion of them; and all this, when there is only some gentle breath of air stirring, without the help of any strong forcible wind. Now I say, if that fowl (which is none of the lightest) can so very easily move it self up and down in the air, without so much as stirring the wings of it: certainely then, it is not improbable, but that when all the due proportions in such an engine are found out, and when men by long practise have arrived to any skill and experience, they will be able in this (as well as in many other things) to come very near unto the imitation of nature.

As it is in those bodies which are carried on the water, though they be never so bigge or so ponderous, (I suppose equall to a City or a whole Island) yet they will alwaies swim on the top, if they be but any thing lighter, then so much water

Sen. Nat. Qu. l. 3. c. 25.

as

as is equall to them in bigneſſe: So likewiſe is it in the bodies that are carried in the air. It is not their greatneſſe (though never ſo immenſe) that can hinder their being ſupported in that light element, if we ſuppoſe them to be extended unto a proportionable ſpace of air. And as from the former experiments, *Archimedes* hath compoſed a ſubtle *ſcience* in his Book, *De inſidentibus humido*, concerning the weight of any heavy body, in reference to the water wherein it is: So from the particular triall of theſe other experiments, that are here inquired after, it is poſſible to raiſe a new ſcience, concerning the extenſion of bodies, in compariſon to the air, and motive faculties by which they are to be carried.

We ſee a great difference betwixt the ſeverall quantities of ſuch bodies, as are commonly upheld by the air; not only little gnats, & flies, but alſo the Eagle and other fowl of vaſter magnitude. *Cardan* and *Scaliger* doe unanimouſly affirm, that there is a *Subtil. l. 10. Exercit. 231.*

bird amongst the Indians of so great a bigness, that his beak is often used to make a sheath or scabbard for a sword. And *Acosta* tels us of a fowl in *Peru* called *Condores*, which will of themselves kill and eat up a whole Calf at a time. Nor is there any reason why any other body may not be supported and carried by the air, though it should as much exceed the quantity of these fowl, as they doe the quantity of a flie.

Hist. Nov. Orb. l. 4. c. 37.

Marcus Polus mentions a fowl in *Madagascar*, which he cals a *Ruck*, the feathers of whose wings are 12 paces, or threescore foot long, which can with as much ease, soop up an Elephant, as our Kites doe a Mouse. If this relation were any thing credible, it might serve as an abundant proof for the present quære. But I conceive this to be already so evident, that it needs not any fable for its further confirmation.

2. The other doubt was, whether the strength of the other persons within it, will be sufficient for the moving

moving of this engine? I answer, the main difficulty and labour of it will be in the raising of it from the ground, neer unto which, the earths attractive vigor, is of greatest efficacy. But for the better effecting of this, it may be helped by the strength of winds, and by taking its first rise from some mountain or other high place. When once it is aloft in the air, the motion of it will be easie, as it is in the flight of all kind of birds, which being at any great distance from the earth, are able to continue their motion for a long time & way, with little labour or wearinesse.

'Tis certain from common relation and experience that many birds doe crosse the seas for divers hundred miles together: sundry of them amongst us, which are of a short wing and flight, as Blackbirds, Nightingales, &c. doe flie from us into *Germany*, and other remoter Countries. And Mariners doe commonly affirm that they have found some fowle above sixe hundred miles from any land. *Plin. l.* 10. *c.* 23.

Now

Now if we ſhould ſuppoſe theſe birds to labour ſo much in thoſe long journies, as they doe when they flie in our ſight and near the earth, it were impoſſible for any of them to paſſe ſo farre without reſting. And therefore it is probable, that they do mount unto ſo a high a place in the air, where the naturall heavineſſe of their bodies does prove but little or no impediment to their flight; Though perhaps either hunger, or the ſight of ſhips, or the like accident, may ſometimes occaſion their deſcending lower, as we may gheſſe of thoſe birds, which Mariners have thus beheld, and divers others that have been drowned and caſt up by the ſea.

Whence it may appear, that the motion of this chariot (though it may be difficult at the firſt) yet will ſtill be eaſier as it aſcends higher, till at length it ſhall become utterly devoid of gravity, when the leaſt ſtrength will be able to beſtow upon it a ſwift motion: as I have proved more

more at large in another discourse.

World in the Moon, c. 14.

But then, (may some object) If it be supposed that a man in the æthereall air does lose his own heavinesse, how shall he contribute any force towards the motion of this instrument?

I answer, The strength of any living creature in these externall motions, is something really distinct from, and superadded unto its naturall gravity: as common experiance may shew, not only in the impression of blows or violent motions, as a river hawk will strike a fowl with a far greater force, then the meer descent or heavinesse of his body could possibly perform. But also in those actions which are done without such help, as the pinching of the finger, the biting of the teeth, &c. all which are of much greater strength then can proceed from the meer heavines of those parts.

As for the other particular doubts, concerning the extream thinnesse, and coldnesse of this æthereal air, by reason of which, it may seem to be al-

altogether impassible; I have already resolved them in the above cited discourse.

The uses of such a Chariot may be various: besides the discoveries which might be thereby made in the lunary world; It would be serviceable also for the conveyance of a man to any remote place of this earth: as suppose to the *Indies* or *Antipodes*. For when once it was elevated for some few miles, so as to be above that orb of magnetick virtue, which is carried about by the earths diurnall revolution, it might then be very easily and speedily directed to any particular place of this great globe.

If the place which we intended were under the same parallel, why then the earths revolution once in 24 howers, would bring it to be under us, so that it would be but descending in a straight line, and wee might presently be there. If it were under any other parallel, it would then only require that we should direct it in the same Meridian, til we did come to that paral-

parallel; and then (as before) a man might easily descend unto it.

It would be one great advantage in this kind of travelling, that one should be perfectly freed from all inconveniences of ways or weather, not having any extremity of heat, or cold, or Tempests to molest him. This æthereall air being perpetually in an equall temper and calmnesse. *Pars superior mundi ordinatior est nec in nubem cogitur, nec in tempestatem impellitur, nec versatur in turbinem, omni tumultu caret, inferiora fulminant.* The upper parts of the world are always quiet and serene, no winds and blustring there, they are these lower clowdy regions that are so full of tempests and combustion.

Sen. de Irâ l. 3. c. 6. Pacem summa tenent. Lucan.

As for the manner how the force of a spring, or (in stead of that) the strength of any living person, may bee applyed to the motion of these wings of the Chariot, it may easily be apprehended from what was formerly delivered.

There are divers other particulars to

to be more fully enquired after, for the perfecting of such a flying Chariot; as concerning the proportion of the wings both for their length and breadth, in comparison to the weight which is to bee carried by them, as also concerning those speciall contrivances, whereby the strength of these wings may be severally applyed either to ascent, descent, progressive, or a turning motion; All which, and divers the like enquiries can onely be resolved by particular experiments. We know the invention of sayling in ships does continually receive some new addition from the experience of every age, and hath been a long while growing up to that perfection, unto which it is now arrived. And so must it be expected for this likewise, which may at first perhaps seeme perplexed with many difficulties and inconveniences, and yet upon the experience of frequent tryals, many things may be suggested to make it more facil and commodious.

As well too long as too short, too broad as too narrow, may be an impediment to the motion, by making it more difficult, slow and flagging.

He

He that would regularly attempt any thing to this purpose, should observe this progresse in his experiments, he should first make enquiry what kind of wings would bee most usefull to this end; those of a Bat being most easily imitable, and perhaps nature did by them purposely intend some intimation to direct us in such experiments; that creature being not properly a bird, because not amongst the *Oviparæ*, to imply that other kind of creatures are capable of flying as well as birds, and if any should attempt it, that would be the best pattern for imitation.

After this he might try what may be effected by the force of springs in lesser models, answerable unto *Archytas* his Dove, and *Regiomontanus* his Eagle: In which he must be carefull to observe the various proportions betwixt the strength of the spring, the heavinesse of the body, the breadth of the wings, the swiftnesse of the motion, &c.

From these he may by degrees ascend to some larger essays. Cap.

Cap. IX.

Of a perpetuall motion. The seeming facility and reall difficulty of any such contrivance. The severall ways whereby it hath been attempted, particularly by Chymistry.

IT is the chief inconvenience of all the *Automata* before mentioned, that they need a frequent repair of new strength, the causes whence their motion does proceed, being subject to fail and come to a period; and therefore it would be worth our enquiry, to examine, whether or no there may be made any such artificiall contrivance, which might have the principle of moving from it self: so that the present motion should constantly be the cause of that which succeeds.

This is that great secret in *art*, which like the Philosophers stone in *nature*, hath been the businesse and study of many more refined wits, for divers ages together; and it may well be questioned, whether either of

of them as yet, hath ever beene found out, though if this have, yet like the other, it is not plainly treated of by any Authour.

Not but that there are sundry discourses concerning this subject, but they are rather *conjectures* then *experiments*. And though many inventions in this kind, may at first view bear a great shew of probability, yet they will fail being brought to triall, and will not answer in practise what they promised in speculation. Any one who hath beene versed in these experiments must needs acknowledge that hee hath been often deceived in his strongest confidence; when the imagination hath contrived the whole frame of such an instrument, and conceives that the event must infallibly answer its hopes; yet then, does it strangely deceive in the proof, and discovers to us some defect, which we did not before take notice of.

Hence is it, that you shall scarce talk with any one who hath never so little smattering in these arts, but he

will instantly promise such a motion, as being but an easie atchievement, till further triall and experience hath taught him the difficulty of it. There being no enquiry that does more entice with the *probability*, and deceive with the *subtilty*. What one speakes wittily concerning the Philosophers stone, may be justly applyed to this, that it is *Casta meretrix*, a chaste whore. *Quia multos invitat, neminem admittit*, because it allures many, but admits none.

I shall briefly recite the severall ways whereby this hath been attempted, or seems most likely to be effected, thereby to contract and facilitate the enquiries of those who are addicted to these kind of experiments; for when they know the defects of other inventions, they may the more easily avoid the same, or the like in their own.

The ways whereby this hath been attempted, may be generally reduced to these three kinds:

1. By Chymicall extractions.

2. By

2. By Magneticall vertues.

3. By the naturall affection of gravity.

1. The discovery of this hath been attempted by Chymistry. *Paracelsus* and his followers have bragged, that by their separations and extractions, they can make a little world which shall have the same perpetuall motions with this *Microcosme*, with the representation of all Meteors, Thunder, snow, rain, the courses of the sea in its ebbs and flows; and the like; But these miraculous promises would require as great a faith to beleeve them, as a power to perform them: And though they often talk of such great matters,

At nusquam tales inter qui talia curant,

Apparet ullus, qui re miracula tanta
Comprobet.

yet we can never see them confirmed by any reall experiment; and then besides, every particular Authour in that art, hath such a distinct language of his own, (all of them being so full

of allegories and affected obscurities) that 'tis very hard for any one (unlesse hee bee throughly versed amongst them) to finde out what they mean, much more to try it.

Etten. Mathem. Recreat. prob. 118.

One of these ways (as I finde it set down) is this. Mixe five ounces of ☿, with an equall weight of ☽, grinde them together with ten ounces of sublimate, dissolve them in a Cellar upon some marble for the space of four days, till they become like oyl olive; distill this with fire of chaffe, or driving fire, and it will sublime into a dry substance: and so by repeating of these dissolvings and distillings, there will bee at length produced divers small atomes, which being put into a glasse well luted, and kept dry, will have a perpetuall motion.

I cannot say any thing from experience against this, but me thinks it does not seem very probable, because things that are forced up to such a vigorousnesse and activity, as these ingredients seem to be by their frequent

quent ſublimatings and diſtillings, are not likely to be of any duration; the more any thing is ſtretched beyond its uſualll nature, the leſſe does it laſt, violence and perpetuity being no companions. And then beſides, ſuppoſe it true, yet ſuch a motion could not well be applied to any uſe, which muſt needs take much from the delight of it.

Amongſt the Chymicall experiments to this purpoſe, may be reckoned up that famous motion invented by *Cornelius Dreble*, and made for King *James*; wherein was repreſented the conſtant revolutions of the Sun and Moone, and that without the help either of ſpring or weights. *Marcellus Vranckhein*, ſpeaking of the means whereby it was performed, he cals it, *Scintillula animæ magneticæ mundi, ſeu Aſtralis & inſenſibilis ſpiritus*; being that grand ſecret, for the diſcovery of which, thoſe Dictators of Philoſophie, *Democritus*, *Pythagoras*, *Plato*, did travell unto the Gymnoſophiſts, and Indian Prieſts.

Celebrated in an Epigram by *Hugo Grotius. l. 1. Epi. Epiſt. ad Erneſtū de Lamp: Vitæ.*

Epist. ad Iacobum Regem.

The Authour himself in his discourse upon it, does not at all reveal the way, how it was performed. But there is one *Thomas Tymme*, who was a familiar acquaintance of his, and did often pry into his works, (as he professes himself) who affirms it to bee done thus; *By extracting a fiery spirit out of the Minerall matter, joyning the same with his proper aire, which included in the Axle tree* (of the first moving wheel) *being hollow, carrieth the other wheels, making a continuall rotation, except issue or vent bee given in this hollow axle tree, whereby the imprisoned spirit may get forth.*

Philosophicall dialogue. *Confer. 2. cap. 3.*

What strange things may be done by such extractions, I know not, and therefore dare not condemn this relation as impossible; but me thinks it sounds rather like a chymicall dream, then a Philosophicall truth. It seems this imprisoned spirit is now set at liberty, or else is grown weary, for the instrument (as I have heard) hath stood still for many years. It is here considerable that any force is weakest near

near the center of a wheel; and therefore though ſuch a ſpirit might of it ſelf have an agitation, yet 'tis not eaſily conceivable how it ſhould have ſtrength enough to carry the wheels about with it. And then the abſurdity of the Authours citing this, would make one miſtruſt his miſtake; he urges it as a ſtrong argument againſt *Copernicus*, as it becauſe *Dreble* did thus contrive in an Engine, the revolution of the heavens, and the immoveableneſſe of the earth, therefore it muſt needs follow that 'tis the heavens which are moved, and not the earth. If his relation were no truer then his conſequence, it had not been worth the citing.

Cap. X.

Of ſubterraneous lamps, divers hiſtoricall relations concerning their duration for many hundred yeares together.

UNto this kind of Chymicall experiments, wee may moſt probably reduce thoſe perpetuall lamps, which for many hundred yeares together have continued burning without any new ſupply in the ſepulchres of the Ancients, and might (for ought wee know) have remained ſo for ever. All fire, and eſpecially flame, being of an active and ſtirring nature, it cannot therefore ſubſiſt without motion; whence it may ſeem, that this great enquiry hath been this way accompliſhed: and therefore it will be worth our examination to ſearch further into the particulars that concern this experiment. Though it be not ſo proper to the chief purpoſe of this diſcourſe, which concerns *Mechanicall Geometry*, yet the ſubtilty and

and curiosity of it, may abundantly requite the impertinency.

There are sundry Authours, who treat of this subject on the by, and in some particular passages, but none that I know of (except *Fortunius Licetus*) that hath writ purposely any set and large discourse concerning it: out of whom I shall borrow many of those relations and opinions, which may most naturally conduce to the present enquiry.

Lib. de reconditis antiquorum lucernis.

For our fuller understanding of this, there are these particulars to be explained:

1. ὅτι, or *quod sit.*
2. διότι { *cur sit.* / *quomodo sit.*

1. First then, for the ὅτι, or that there have been such lamps, it may be evident from sundry plaine and undeniable testimonies: Saint *Austin* mentions one of them in a Temple dedicated to *Venus*, which was always exposed to the open weather, and could never be consumed or extinguished. To him assents the judicious

De civitat. Dei l. 21. c. 6.

De operibus Dei, pars 1. l. 4. c. 12. De deperd. Tit. 35.

ous *Zanchy*. *Pancyrollus* mentions a Lamp found in his time, in the ſepulchre of *Tullia*, *Cicero's* daughter, which had continued there for about 1550 years, but was preſently extinguiſhed upon the admiſſion of new air. And 'tis commonly related of *Cedrenus*, that in *Juſtinians* time there was another burning lamp found in an old wall at * *Edeſſa*, which had remained ſo for above 500 years, there being a crucifixe placed by it, whence it ſhould ſeem, that they were in uſe alſo amongſt ſome Chriſtians.

* Or *Antioch. Lucetum de Lucernis, l. 1. c. 7.*

But more eſpecially remarkable, is that relation celebrated by ſo many Authours, concerning *Olybius* his lamp, which had continued burning for 1500 years. The ſtory is thus: As a ruſtick was digging the ground by *Padua*, he found an Urne or earthen pot, in which there was another urne, and in this leſſer, a lamp clearly burning; on each ſide of it, there were two other Veſſels, each of them full of a pure liquor, the one of gold, the other of ſilver. *Ego Chymiæ artis, (ſi modo*

modo vera poteſt eſſe ars Chymica) jurare auſim elementa & materiam omnium, (ſaith *Maturantius*, who had the poſſeſſion of theſe things after they were taken up.) On the bigger of theſe urns there was this inſcription:

Plutoni ſacrum munus ne attingite fures,
Ignotũ eſt vobis hoc quod in orbe latet,
Namque elementa gravi clauſit digeſta labore
Vaſe ſub hoc modico, Maximus Olybius.
Adſit fœcundo tuſtes ſibi copia cornu,
Ne tanti pretium depereat laticis.

The leſſer urn was thus inſcribed:

Abite hinc peßimi fures,
Vos quid vultis, veſtris cum oculis emißitiis?
Abite hinc, veſtro cum Mercurio
Petaſato Caduceatoque,
Donum hoc Maximum, Maximus Olybius
Plutoni ſacrum facit.

Whence wee may probably conjecture that it was ſome Chymicall ſecret,

cret, by which this was contrived.

Mag. Natural. l. 12. cap. ult. *Baptista Porta* tels us of another lamp burning in an old marble sepulchre, belonging to some of the ancient Romans, inclosed in a glasse viall, found in his time, about the year 1550, in the Isle *Nesis*, which had been buried there before our Saviours coming.

Chron. Martin. Fort. Licet. de lucern. l. 1. c. 11. In the Tombe of *Pallas*, the Arcadian who was slain by *Turnus* in the Trojan war, there was found another burning lamp, in the year of our Lord 1401. Whence it should seem, that it had continued there for above two thousand and six hundred years: and being taken out, it did remain burning, notwithstanding either wind or water, with which some did strive to quench it; nor could it be extinguished till they had spilt the liquor that was in it.

Not: ad August: de civit. Dei, l. 21. c. 6. *Ludovicus Vives* tels us of another lamp that did continue burning for 1050 years, which was found a little before his time.

Such a lamp is likewise related to be

be seen in the sepulchre of *Francis Rosicrosse*, as is more largely expressed in the confession of that fraternity.

There is another relation of a certain man, who upon occasion digging somewhat deep in the ground, did meet with something like a dore, having a wall on each hand of it, from which having cleared the earth, he forced open this dore, upon this there was discovered a faire Vault, and towards the further side of it, the statue of a man in Armour, sitting by a table, leaning upon his left arm, and holding a scepter in his right hand, with a lamp burning before him, the floor of this Vault being so contrived, that upon the first step into it, the statue would erect it self from its leaning posture, upon the second step it did lift up the scepter to strike, and before a man could approach near enough to take hold of the lamp, the statue did strike and break it to peeces. such care was there taken that it might not be stoln away, or discovered.

Our learned *Cambden* in his descrip- Pag. 572.

tion

tion of *Yorkshire*, speaking of the tombe of *Constantius Chlorus*, broken up in these later years, mentions such a lamp to be found within it.

There are sundry other relations to this purpose. *Quod ad lucernas attinet, illa in omnibus fere monumentis inveniuntur*, (saith *Gutherius*.) In most of the ancient Monuments there is some kind of lamp, (though of the ordinary sort,) But those persons who were of greatest note and wisdome, did procure such as might last without supply, for so many ages together. *Pancirollus* tels us that it was usuall for the Nobles amongst the Romans, to take speciall care in their last wils, that they might have a lamp in their Monuments. And to this purpose they did usually give liberty unto some of their slaves on this condition, that they should be watchfull in maintaining and preserving it. From all which relations, the first particular of this enquiry, concerning the being or existence of such lamps, may sufficiently appear.

De jure manium, l. 2. c. 32.

De perdit. Tit. 62.

Cap.

Cap. XI.

Severall opinions concerning the nature and reason of these perpetuall Lamps.

THere are two opinions to be answered, which doe utterly overthrow the chiefe consequence from these relations.

1. Some think that these lights so often discovered in the ancient tombs, were not fire or flame, but only some of those bright bodies which do usually shine in dark places.

2. Others grant them to be fire, but yet think them to be then first enkindled by the admission of new air, when these sepulchres were opened.

1. There are divers bodies (saith *Aristotle*) which shine in the dark, as rotten wood, the scales of some fishes, stones, the glow-worm, the eyes of divers creatures. *Cardan* tels us of a bird in new *Spain*, called *Cocyum*, whose whole body is very bright, but his eyes almost equall to the light of

De anima. l. 2. c. 8.

Subtil. l. 9.

a candle, by which alone in a darke night, one may both write and read; By these the Indians (saith he) use to eat their feasting Suppers.

It is commonly related and beleeved, that a Carbuncle does shine in the dark like a burning coal, from whence it hath its * name. To which purpose there is a story in *Ælian*, of a Stork, that by a certain woman was cured of a broken thigh, in gratitude to whom, this fowl afterwards flying by her, did let fall into her lap a bright Carbuncle, which (saith he) would in the night time shine as clear as a lamp. But this and the like old relations are now generally disbeleeved and rejected by learned men: *Doctißimorum omnium consensu, hujusmodi gemmæ non inveniuntur*, (saith *Boetius de Boot*) a man very much skilled in, and inquisitive after such matters, nor is there any one of name that does from his own eye-sight or experience, affirm the reall existence of any gem so qualified.

* *Carlo Pyropus. Historia Animal. l. 8*

De Lapid. & Gemmis. l. 2. c. 8.

Some have thought that the light in

in ancient tombs hath been occasioned from some such bodies as these. For if there had been any possibility to preserve fire so long a space, 'tis likely then that the *Israelites* would have known the way, who were to keep it perpetually for their sacrifices.

Vide Licet. de lucern. l. 2.

But to this opinion it might bee replyed, that none of these *Noctiluca*, or night-shining bodies have been observed in any of the ancient sepulchres, and therefore this is a mere imaginary conjecture; And then besides, some of these lamps have been taken out burning, and continued so for a considerable space afterwards. As for the supposed conveniency of them, for the perpetuating of the holy fire amongst the Jews, it may as well be feared lest these should have occasioned their idolatry; unto which that nation was so strongly addicted, upon every sleight occasion; nor may it seem strange, if the providence of God should rather permit this fire sometimes to goe out, that so by their earnest prayers, being a-

gain renued from heaven, (as it * sometimes was) the peoples faith might be the better stirred up and strengthned, by such frequent miracles.

2. It is the opinion of *Gutherius*, that these lamps have not continued burning for so long a space, as they are supposed in the former relations, but that they were then first enflamed by the admission of new air, or such other occasion, when the sepulchres were opened: as we see in those fat earthy vapours of divers sorts, which are oftentimes enkindled into a flame. And 'tis said, that there are some Chymicall ways, whereby iron may be so heated, that being closely luted in a glasse, it shall constantly retain the fire for any space of time, though it were for a thousand years or more; at the end of which, if the glasse be opened, and the fresh aire admitted, the iron shall be as red hot as if it were newly taken out of the fire.

But for answer to this opinion, 'tis considerable that some urns have had inscrip-

* Levit. 9. 24. 2 Chron. 7. 1. 1 King. 18. 38.

De jure Manii. l. 2. c. 32.

inſcriptions on them, expreſſing that the lamps within them were burning, when they were firſt buried. To which may be added the experience of thoſe which have continued ſo, for a good ſpace afterwards; whereas the inflammation of fat and viſcous vapours does preſently vaniſh. The lamp which was found in the Iſle *Neſis*, did burn clearly while it was incloſed in the glaſſe, but that being broken, was preſently extinguiſhed. As for that Chymicall relation, it may rather ſerve to prove, that fire may continue ſo many ages, without conſuming any fewell.

So that notwithſtanding the oppoſite opinions, yet 'tis more probable that there have been ſuch lamps, as have *remained burning*, without any new ſupply, for many hundred years together; which was the firſt particular to be explained.

2. Concerning the reaſon, why the Ancients were ſo carefull in this particular, there are divers opinions. Some think it to be an expreſſion of *Cur ſint.*

their beleef, concerning the ſouls immortality, after its departure out of the body, a lamp amongſt the *Egyptians* being the *Hieroglyphick* of life. And therefore they that could not procure ſuch lamps, were yet carefull to have the image and repreſentation of them ingraved on their Tombes.

Others conceive them to be by way of gratitude to thoſe infernall deities, who tooke the charge and cuſtody of their dead bodies, *remaining* always with them in their Tombs, and were therefore called *Dii manes*.

Others are of opinion, that theſe lamps were onely intended to make their ſepulchres more pleaſant and lightſome, that they might not ſeem to be impriſoned in a diſmall and uncomfortable place. True indeed, the dead bodie cannot be ſenſible of this light, no more could it of its want of burial; yet the ſame inſtinct which did excite it to the deſire of one, did alſo occaſion the other.

De Lucernis, l. 3. c. 8. *Licetus* concludes this ancient cuſtome to have a double end. 1. *Politick*,

litick, for the distinction of such as were nobly born, in whose monuments only they were used. 2. *Naturall*, to preserve the body and soul from darkness; For it was a common opinion amongst them, that the souls also were much conversant about those places where the bodies were buried.

CAP. XII.

The most probable conjecture how these lamps were framed.

THe greatest difficulty of this enquiry doth consist in this last particular, concerning the manner how, or by what possible means any such perpetuall flame may be contrived. *Quomodo fiat.*

For the discovery of which, there are two things to be more especially considered.

1. The snuffe or wick, which must administer unto the flame.

2. The oyl, which must nourish it.

For the first, it is generally granted that there are divers substances which will retain fire without consuming: such is that minerall which they call the Salamanders wool, saith our learned * *Bacon*. *Ipse expertus sum villos Salamandræ non consumi*, saith † *Joachimus Fortius*. And * *Wecker* from his own knowledge affirms the same of *plumeallum*, that being formed into the likenesse of a wick, will administer to the flame, and yet not consume it self. Of this nature likewise was that which the Ancients did call *linum vivum*, or *asbestinum*: of this they were wont to make garments, that were not destroyed, but purified by fire; and whereas the spots or foulnesse of other cloaths are washed out, in these they were usually burnt away. The bodies of the ancient Kings were wrapped in such garments when they were put in the funerall pile, that their ashes might bee therein preserved, without the mixture of any other. The materials of them were not from any hearb or vegetable.

* *Nat. hist. exper. 774.*
† *Lib. exper.*
* *De Secretis, l. 3. c. 2.*

Or *Linum Carpasium. Plutarch, de Oracul. defectu.*

Plin. Hist. l. 19. c. 1.

ble, as other textils, but from a ſtone called *Amiantus*, which being bruiſed by a hammer, and its earthy nature ſhaken out, retains certain hairy ſubſtances, which may be ſpun and woven as hemp or flaxe. *Pliny* ſays, that for the precioufneſſe of it, it did almoſt equall the price of pearls. *Pancirollus* tels us, that it was very rare and eſteemed precious in ancient times, but now is ſcarce found or known in any places, and therefore he reckons it amongſt the things that are loſt. But *L. Vives* affirms, that he hath often ſeen wieks made of it at *Paris*, and the ſame matter woven into a napkin at *Lovaine*, which was cleanſed by being burnt in the fire.

Deperd. Tit. 4.

In Auguſt. de civit. Dei, l. 21. c. 6.

'Tis probable from theſe various relations, that there was ſeverall ſorts of it, ſome of a more precious, other of a baſer kinde, that was found in *Cyprus*, the deſerts of *India*, and a certain Province of *Aſia*: this being common in ſome parts of *Italy*, but is ſo ſhort and brittle, that it cannot be ſpun into a thred. And

therefore is usefull only for the wicks of perpetuall lamps, saith *Boetius de Boot.* Some of this, or very like it, I have upon inquiry lately procured and experimented. But whether it be the stone *Asbestus*, or only *plumeallum*, I cannot certainly affirm. For it seems they are both so very like, as to be commonly sold for one another (saith the same Authour.) However it does truly agree in this common quality ascribed unto both, of being incombustible, and not consumable by fire: But yet there is this inconvenience, that it doth contract so much fuliginous matter from the earthy parts of the oyl, (though it was tryed with some of the purest oyl, which is ordinary to be bought) that in a very few days it did choak and extinguish the flame. There may possibly be some chymicall way so to purifie and defecate this oyl, that it shall not spend into a sooty matter.

D Lapid. et gemmis, l. 2. c. 204.

However if the liquour be of a close and glutinous consistency, it may burn without any snuffe, as we see in

in Camphire, and ſome other bituminous ſubſtances. And it is probable that moſt of the ancient lamps were of this kind, becauſe the exacteſt relations (to my remembrance) doe not mention any that have been found with ſuch wieks.

But herein will conſiſt the greateſt difficulty, to find out what invention there might be for their duration. Concerning which there are ſundry opinions.

Saint *Auſtin* ſpeaking of that lamp in one of the Heathen Temples, thinks that it might either be done by Magick, the Devill thinking thereby to promote the worſhip and eſteem of that idoll to which it was dedicated, or elſe that the art of man might make it of ſome ſuch materiall, as the ſtone *Aſbeſtus*, which being once enkindled, will burn without being conſumed. As others (ſaith he) have contrived as great a wonder in appearance, from the naturall virtue of another ſtone, making an iron image ſeem to hang in the air, by rea-

De civ. Dei l. 21. c. 6.

Zarch. de Operibus Dei, par. 1. l. 4. c. 12.

reason of two load-stones, the one being placed in the seeling, the other in the floor.

Others are of opinion that this may be effected in a hollow vessell, exactly luted or stopped up in all the vents of it. And then, if a lamp be supposed to burn in it, but for the least moment of time, it must continue so always, or else there would be a *Vacuũ*, which nature is not capable of; If you ask, how it shall be nourished, it is answered, that the oyl of it being turned into smoak & vapours, will again be converted into its former nature; For otherwise, if it should remaine rarified in so thin a substance, then there would not be room enough for that fume which must succeed it, and so on the other side, there might bee some danger of the *penetration* of bodies, which nature doth as much abhor. To prevent both which, as it is in the chymicall circulations, where the same body is oftentimes turned from liquour into vapour, and from vapour into liquour again, so

in

in this experiment, the ſame oyl ſhall be turned into fume, and that fume ſhall again convert into oyl. Always provided, that this oyl which nouriſhes the lamp, bee ſuppoſed of ſo cloſe and tenacious a ſubſtance, that may ſlowly evaporate; and ſo there will be the more leiſure for nature to perfect theſe circulations. According to which contrivance, the lamp within this veſſell can never fail, being always ſupplyed with ſufficient nouriſhment. That which was found in the Iſle *Neſis*, incloſed in a glaſſe viall, mentioned by *Baptiſta Porta*, is thought to be made after ſome ſuch manner as this.

Others conceive it poſſible to extract ſuch an oyl out of ſome minerals, which ſhall for a long ſpace ſerve to nouriſh the flame of a lamp with very little or no expence of its own ſubſtance. To which purpoſe (ſay they) if gold be diſſolved into an unctuous humour, or if the radicall moiſture of that metall were ſeparated, it might be contrived to burne (perhaps

Wolphang. Lazius, l. 3 c. 18. Camb. Brit. p. 572.

(perhaps for ever, or at least) for many ages together, without being consumed. For if gold it self (as experience shews) be so untameable by the fire, that after many meltings, and violent heats, it does scarce diminish, 'tis probable then, that being dissolved into an oylie substance, it might for many hundred years together continue burning.

There is a little chymical discourse to prove that *Vrim* and *Thummim* is to be made by art; the Authour of this Treatise affirms that place, *Gen.* 6.16. where God tels *Noah, a window shalt thou make in the Ark*, to be very unfitly rendred in our translation a window, because the original word צהר signifies properly splendor or light; and then besides, the air being at that time so extreamely darkned with the clouds of that excessive rain, a window could be but of very little use in regard of light, unless there were some other help for it; From whence he conjectures that both this splendor, and so likewise the Urim

and

and Thummim were artificiall, chymicall preparations of light, answerable to these subterraneous lamps; or in his own phrase, it was *the universall spirit fixed in a transparent body.*

It is the opinion of *Licetus* (who hath more exactly searched into the subtilties of this inquiry) that fire does not need any humour for the nourishment of it, but onely to defin it from flying upwards. For being it self one of the chief elements (saith he out of *Theophrastus*) it were absurd to think that it could not subsist without something to feed it. As for that substance which is consumed by it, this cannot be said to foment or preserve the same fire, but onely to generate new. For the better understanding of this, we must observe, that there may be a threefold proportion betwixt fire, and the humour or matter of it. Either the humour does exceed the strength of the fire, or the fire does exceed the humour; and according to both these, the flame doth presently vanish. Or else

De Lucernis, c. 20, 21

elſe laſtly, they may be both equall in their virtues, (as it is betwixt the radicall moiſture and naturall heat in living creatures) and then neither of them can overcome or deſtroy the other.

Thoſe ancient lamps of ſuch long duration were of this later kind. But now, becauſe the qualities of heat or cold, drineſſe or moiſture in the ambient air, may alter this equality or proportion betwixt them, and make one ſtronger then the other; therefore to prevent this, the Ancients did hide theſe lamps in ſome caverns of the earth, or cloſe monuments: And hence is it, that at the opening of theſe, the admiſſion of new air unto the lamp does uſually cauſe ſo great an inequality betwixt the flame and the oyle, that it is preſently extinguiſhed.

But ſtill the greateſt difficulty remains, how to make any ſuch exact proportion betwixt an unctuous humour, and ſuch an active quality, as the heat of fire, or this equality being

ing made, it is yet a further difficulty, how it may bee preſerved. To which purpoſe, *Licetus* thinkes it poſſible to extract an inflamable oyl from the ſtone *Aſbeſtus*, *Amiantus*, or the metall gold, which being of the ſame pure and homogeneous nature with thoſe bodies, ſhall be ſo proportioned unto the heat of fire, that it cannot be conſumed by it, but being once inflamed ſhould continue for many ages, without any ſenſible diminution.

If it be in the power of Chymiſtry to perform ſuch ſtrange effects, as are commonly experimented in that which they call *aurum fulminans*, one ſcruple of which ſhall give a lowder blow, & be of greater force in deſcent, then half a pound of ordinary gunpowder in aſcent; why may it not be as feaſible by the ſame art to extract ſuch an oyl as is here enquired after: Since it muſt needs be more difficult to make a fire which of its owne inclination ſhall tend downewards, then to contrive ſuch an unctuous

ctuous liquour, wherein fire ſhall be maintained for many years without any new ſupply.

Thus have I briefly ſet down the relations and opinions of divers learned men concerning theſe perpetuall lamps; of which, though there have been ſo many ſundry kinds, and ſeverall ways to make them, (ſome being able to reſiſt any violence of weathers, others being eaſily extinguiſhed by any little alteration of the air, ſome being incloſed round about within glaſſe, others being open;) yet now they are all of them utterly periſhed amongſt the other ruines of time; and thoſe who are moſt verſed in the ſearch after them have onely recovered ſuch dark conjectures, from which a man cannot clearly deduce any evident principle that may encourage him to a particular triall.

Cap.

Cap. XIII.

Concerning ſeverall attempts of contriving a perpetuall motion by magneticall virtues.

THe ſecond way whereby the making of a perpetuall motion hath been atttempted, is by magneticall virtues; which are not without ſome ſtrong probabilities of proving effectuall to this purpoſe: eſpecially when we conſider that the heavenly revolutions, (being as the firſt pattern imitated and aimed at in theſe attempts) are all of them performed by the help of theſe qualities. This great orb of earth, and all the other planets being but as ſo many magneticall globes endowed with ſuch various and continuall motions, as may be moſt agreeable to the purpoſes for which they were intended. And therefore moſt of the Authours, who treat concerning this invention, do agree, that the likelieſt way to effect it, is by theſe kind of qualities.

It was the opiniō of *Pet: Peregrinus*, & there is an example pretended for it in *Betttinus* (*Apiar.9.Progym.5.pro.* 11.) that a magneticall globe or terella, being rightly placed upon its poles, would of it self have a constant rotation, like the diurnall motion of the earth; But this is commonly exploded, as being against all experience.

Gilbert de Magnet. Cabæus Philos. Magnet. l.4.c.20.

Others think it possible, so to contrive severall pieces of steel, and a loadstone, that by their continuall attraction and expulsion of one another, they may cause a perpetuall revolution of a wheel; Of this opinion were [a] *Taisner*, [b] *Pet. Peregrinus*, and [c] *Cardan*, out of *Antonius de Fantis*. But D. *Gilbert*, who was more especially versed in magneticall experiments, concludes it to be a vain and groundlesse fancy.

At hanc as. Kircher, de Arte Magnet. l.1.par. 2.prop.13. Item l.2. p.4.

[a] *Tract. de motu continuo.*
[b] *De Rota perpetui motus.par. 1.c.3.*
[c] *De Variet. rerū l.9.c.48. De magnet. l.2.c.35.*

But amongst all these kind of inventions, that is most likely, wherein a loadstone is so disposed, that it shall draw unto it on a reclined plane, a bullet of steel; which steele, as it ascends

ſcends neer to the loadſtone, may be contrived to fall down through ſome hole in the plane, and ſo to return unto the place from whence at firſt it began to move; and being there, the loadſtone will again attract it upwards, till coming to this hole it will fall down again: and ſo the motion ſhall be perpetuall, as may be more eaſily conceivable by this figure.

Suppose the loadstone to be represented at *A B*, which though it have not strength enough to attract the bullet *C*, directly from the ground, yet may doe it by the help of the plane *E F*; Now when the bullet is come to the top of this plane, its own gravity (which is supposed to exceed the strength of the loadstone) will make it fall into that hole at *E*: and the force it receives in this fall, will carry it with such a violence unto the other end of this arch, that it will open the passage which is there made for it, and by its return will again shut it, so that the bullet, (as at the first) is in the same place, whence it was attracted, and consequently must move perpetually.

But however this invention may seem to be of such strong probability, yet there are sundry particulars which may prove it insufficient. For,

1. This bullet of steele must first be touched and have its severall poles, or else there can be little or no attraction of it. Suppose *C* in the steel to

to be answerable unto *A* in the stone, and to *B*; In the attraction *C D*, must always be directed answerable to *A B*, and so the motion will be more difficult, by reason there can be no rotation or turning round of the bullet, but it must slide up with the line *C D*, answerable to the axis *A B*.

2. In its fall from *E* to *G*, which is *motus elementaris*, and proceeds from its gravity, there must needs be a rotation of it, and so 'tis ods, but it happens wrong in the rise, the poles in the bullet, being not in the same direction to those in the magnet; and if in this refluxe it should so fall out, that *D* should be directed towards *B*, there should be rather a flight then an attraction, since those two ends doe *repell* and not draw one another.

3. If the loadstone *A B*, have so much strength that it can attract the bullet in *F*, when it is not turned round, but does onely slide upon the plane, whereas its own gravity would roule it downwards: then it is evident,

the ſphere of its activity and ſtrength would be ſo increaſed when it approaches much neerer, that it would not need the aſſiſtance of the plane, but would draw it immediately to it ſelf, without that help, and ſo the bullet would not fal down through the hole, but aſcend to the ſtone, and conſequently ceaſe its motion. For if the loadſtone be of force enough to draw the bullet on the plane, at the diſtance *F B*, then muſt the ſtrength of it be ſufficient to attract it immediately unto it ſelfe, when it is ſo much neerer as *E B*. And if the gravity of the bullet be ſuppoſed ſo much to exceed the ſtrength of the Magnet, that it cannot draw it directly when it is ſo neat, then will it not be able to attract the bullet up the plane when it is ſo much further off.

So that none of all theſe Magneticall experiments, which have been as yet diſcovered, are ſufficient for the effecting of a perpetuall motion, though theſe kind of qualities ſeem moſt conducible unto it, and perhaps

haps hereafter it may be contrived from them.

Cap. XIV.

The seeming probability of effecting a continuall motion by solid weights in a hollow wheel or sphere.

THe third way whereby the making of a perpetuall motion hath been attempted, is by the naturall affection of gravity; when the heavinesse of severall bodies is so contrived, that the same motion which they give in their descent, may bee able to carry them up again.

But against the possibility of any such invention, it is thus objected by *Cardan*; All sublunary bodies have a direct motion either of ascent or descent, which, because it does refer to some tearm, therefore cannot be perpetuall, but must needs cease, when it is arrived at the place unto which it naturally tends.

Subtilitat. De Var. Rerum l. 9. c. 48.

I answer, though this may prove

that there is no naturall motion of any particular heavy body, which is perpetuall, yet it doth not hinder but that it is possible from them to contrive such an artificiall revolution as shall constantly be the cause of it self.

Those bodies which may be serviceable to this purpose, are distinguishable into two kinds.

1. Solid and consistent, as weights of metall, or the like.

2. Fluid or sliding, as water, sand, &c.

Both these ways have been attempted by many, though with very little or no successe. Other mens conjectures in this kind you may see set down by divers Authours. It would be too tedious to repeat them over, or set forth their draughts. I shall onely mention two new ones, which (if I am not over partiall) seem altogether as probable, as any of these kinds that have been yet invented; and til experience had discovered their defect and insufficiency, I did certainly

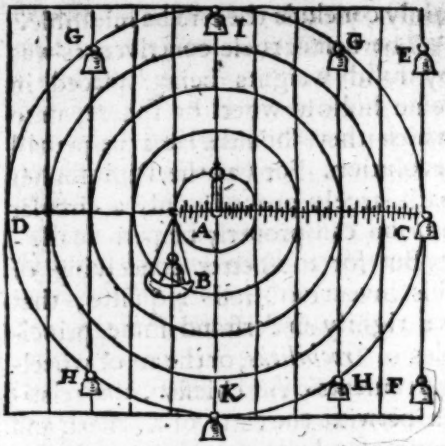
D. Flud. Tract. 2. part 3 l. 2. c. 4. & 7.

tainly conclude them to be infallible.

The first of these contrivances was by solid weights being placed in some hollow wheel or sphere, unto which they should give a perpetuall revolution. For (as the Philosopher hath largely proved) only a circular motion can properly be perpetuall. *Arist. Phys. l. 8. c. 12.*

But for the better conceiving of this invention, it is requisite, that we rightly understand some principles in *Trochilicks*, or the art of wheel-instruments; As chiefly, the relation betwixt the parts of a wheel, and those of a ballance: the severall proportions in the Semidiameter of a wheel, being answerable to the sides in a ballance, where the weight is multiplyed according to its distance from the center. *Arist. Mechan. c. 2. De ratione libræ ad circulum.*

Thus



Thus suppose the center to be at *A*, and the Diameter of the wheel *D C*, to be divided into equall parts (as is here expressed) it is evident according to the former ground, that one pound at *C*, will equiponderate to five pound at *B*, because there is such a proportion betwixt their severall distances from the Center. And it is not materiall whether or no these severall weights be placed horizontally, for though *B* do hang lower then

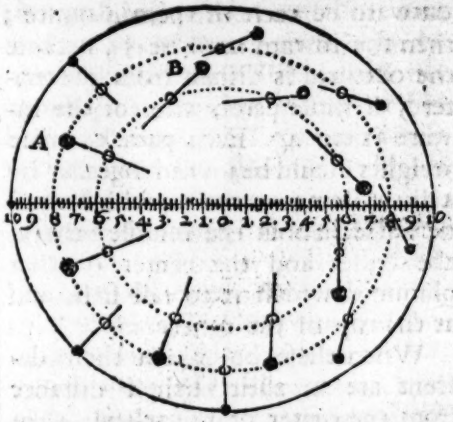
then *C*, yet this does not at all concern the heavineſſe, or though the plummet *C*, were placed much higher then it is at *E*, or lower at *F*, yet would it ſtill retain the ſame weight which it had at *C*, becauſe theſe plummets (as is the nature of all heavy bodies) doe tend downewards by a ſtreight line: So that their ſeverall gravities are to be meaſured by that part of the horizontall Semidiameter, which is directly either below or above thē. Thus when the plummet *C*, ſhall be moved either to *G* or *H*, it wil loſe ½ of its former heavineſſe, and bee equally ponderous as if it were placed in the ballance at the number 3, and if we ſuppoſe it to be ſituated at *I* or *K*, then the weight of it will lie wholly upon the Center, and not at all conduce to the motion of the wheel on either ſide. So that the ſtreight lines which paſſe through the diviſions of the diameter, may ſerve to meaſure the heavineſſe of any weight in its ſeverall ſituations.

Theſe things throughly conſidered, it

it seems very possible and easie for a man to contrive the plummets of a wheel, that they may be always heavier in their fall, then in their ascent; and so consequently that they should give a perpetuall motion to the wheel it self: Since it is impossible for that to remain unmoved, as long as one side in it is heavier then the other.

For the performance of this, the weights must be so ordered, 1. That in their descent they may fall from the Center, and in their ascent may rise neerer to it. 2. That the fall of each plummet may begin the motion of that which should succeed it. As in this following Diagram.

Where



Where there are 16 plummets, 8 in the inward circle, and as many in the outward, (the inequality being to arise from their situation, it is therefore most convenient that the number of them be even.) The eight inward plummets are supposed to be in themselves so much heavier then the other, that in the wheel they may be of equall weight with those above them, and then the fall of these will bee of sufficient force to bring down

down the other. For example, if the outward be each of them 4 ounces, then the inward must be 5, because the outward is distant from the center 5 of those parts, whereof the inward is but 4. Each paire of these weights should be joyned together by a little string or chain, which must be fastned about the middle betwixt the bullet and the center of that plummet, which is to fall first, and at the top of the other.

When these bullets in their descent are at their fartheſt distance from the center of the wheel, then shall they be stopped, and rest on the pins placed to that purpose; and so in their rising, there must be other pins to keep them in a convenient posture and distance from the center, lest approaching too neere unto it, they thereby become unfit to fall, when they shall come to the top of the descending side.

This may be otherwise contrived with some different circumstances, but they will all redound to the same effect.

effect. By ſuch an engine it ſeemes very probable, that a man may produce a perpetuall motion. The diſtance of the plummets from the center increaſing their weight on one ſide, and their being tyed to one another, cauſing a conſtant ſucceſſion in their falling.

But now, upon experience I have found this to be fallacious, & the reaſon may ſufficiently appear by a calculation of the heavines of each plummet, according to its ſeveral ſituation, which may eaſily be done by thoſe perpendiculars that cut the diameter, (as was before explained, and is here expreſſed in five of the plummets on the deſcending ſide.) From ſuch a calculation it will be evident, that both the ſides of this wheel will equiponderate, and ſo conſequently that the ſnppoſed inequality, whence the motion ſhould proceed, is but imaginary and groundleſſe. On the deſcending ſide, the heavineſſe of each plummet may be meaſured according to theſe numbers, (ſuppoſing the diameter

ameter of the wheel to be divided into twenty parts, and each of those subdivided into four.)

The outward plummets.			*The inward plummets.*		
7	0		1	0	
10	0	*The sum* 24.	7	2	*The sum* 19.
7	0		7	2	
			3	0	

On the ascending side the weights are to be reckoned according to these degrees.

The outward.			*The inward.*		
1	3		4	1	
7	2		7	0	
9	0	*The sum* 24.	5	2	*The sum* 19.
5	3		2	1	
0	0				

The summe of which last numbers is equall with the former, and therefore both the sides of such a wheele, in this situation will equiponderate.

If

If it be objected, that the plummet *A* should bee contrived to pull down the other at *B*, and then the descending side will be heavier then the other.

For answer to this, it is considerable,

1. That these bullets towards the top of the wheel, cannot descend till they come to a certain kind of inclination.

2. That any lower bullet hanging upon the other above it, to pull it down, must be conceived, as if the weight of it were in that point where its string touches the upper, at which point this bullet will be of lesse heavinesse in respect of the wheel, then if it did rest in its own place: So that both the sides of it in any kind of situation may equiponderate.

Cap. XV.

Of compasing a perpetuall motion by fluid weights. Concerning Archimedes *his water-screw. The great probability of accomplishing this inquiry by the help of that, with the fallibleness of it upon experiment.*

THat which I shall mention as the last way, for the triall of this experiment, is by contriving it in some water instrument, which may seem altogether as probable and easie as any of the rest, because that element by reason of its fluid and subtle nature (whereby of its own accord it searches out the lower and more narrow passages) may be most pliable to the mind of the artificer. Now the usuall means for the ascent of water is either by *Suckers* or *Forces*, or something equivalent thereunto; Neither of which may be conveniently applied unto such a work as this, because there is required unto each of them so much or more strength, as may be answerable

ble to the full weight of the water that is to be drawn up; and then besides, they move for the most part by fits and snatches, so that it is not easily conceivable, how they should conduce unto such a motion, which by reason of its perpetuity must bee regular and equall.

But amongst all other ways to this purpose, that invention of *Archimedes* is incomparably the best, which is usually called *Cochlea*, or the *water-screw*, being framed by the helicall revolution of a cavity about a Cylinder. We have not any discourse from the Authour himself concerning it, nor is it certain whether he ever writ any thing to this purpose. But if he did, yet as the injury of time hath deprived us of many other his excellent workes, so likewise of this, amongst the rest.

Athenæus speaking of that great ship built by *Hiero*, in the framing of which, there were 300 Carpenters employed for a year together, besides many other hirelings for carriages, Dipnosoph. l. 5.

and ſuch ſervile works, mentions this inſtrument as being in ſtead of a pump for that vaſt ſhip, by the help of which, one man might eaſily and ſpeedily drain out the water, though it were very deep.

Biblioth. L. 1.

Diodorus Siculus ſpeaking of this engine, tels us, that *Archimedes* invented it when hee was in Ægypt, and that it was uſed in that Country for the draining of thoſe pits and lower grounds, whence the waters of *Nilus* could not return. Φιλοτέχνου δ' ὄντος τοῦ ὀργάνου καθ' ὑπερβολὴν, (ſaith the ſame Authour.) It being an engine ſo ingenious and artificiall, as cannot be ſufficiently expreſſed or commended. And ſo (it ſhould ſeeme) the Smith in Millain conceived it to be, who having without any teaching or information found it out, and therefore thinking himſelf to be the firſt inventer, fell mad with the meer joy of it.

Cardan Subt. L. 1. De ſapient. L. 5.

The nature and manner of making this, is more largely handled by *Vitruvius*.

Architect. L. 10. c. 11.

The

The figure of it is after this manner.

Where you see there is a Cylinder *AA*, and a spirall cavity or pipe twining about it, according to equall revolutions *BB*. The axis and centers of its motions are at the points *C D*, upon which being turned, it will so happen that the same part of the pipe which was now lowermost, will presently become higher, so that the water does ascend by descending, ascending in comparison to the whole instrument, and descending in respect

of its severall parts. This being one of the strangest wonders amongst those many, wherein these Mathematicall arts doe abound, that a heavy body should rise by falling down, and the farther it passes by its own naturall motion of descent, by so much higher still shall it ascend; which though it seem so evidently to contradict all reason and Philosophy, yet in this instrument it may be manifested both by demonstration and sense.

This pipe or cavity for the matter of it, cannot easily be made of metall, by reason of its often turnings; but for triall, there might be such a cavity cut in a columne of wood, and afterwards covered over with tinne plate.

For the form and manner of making this screw, *Vitruvius* does prescribe these two rules:

1. That there must be an equality observed betwixt the breadth of the pipe, and the distance of its severall circumvolutions.

2. That there must be such a proportion

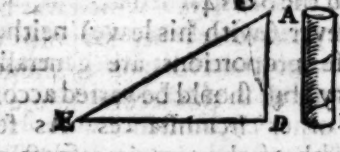
portion betwixt the length of the instrument, and its elevation, as is answerable to the *Pythagoricall Trigon*. If the Hypotenusall, or Screw be 5, the perpendicular or elevation must be 3, and the basis 4.

David Rivalt. Com. in Archim. opera extern.

However (with his leave) neither of these proportions are generally necessary, but should be varied according to other circumstances. As for the breadth of the pipe in respect of its revolutions; it is left at liberty, and may bee contrived according to the quantity of water which it should contain. The chief thing to be considered is the obliquity or closenesse of these circumvolutions. For the nearer they are unto one another, the higher may the instrument be erected; there being no other guide for its true elevation but this.

And because the right understanding of this particular is one of the principall matters that concerns the use of this engine, therefore I shall endeavour with brevity and perspicuity to explain it. The first thing

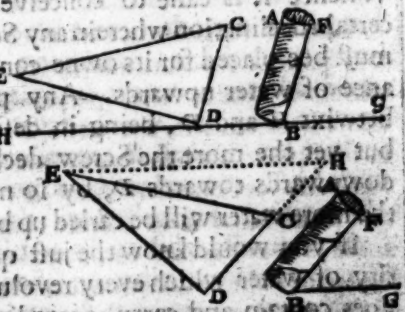
to be inquired after is what kind of inclination theſe Helicall revolutions of the cylinder have unto the Horizon, which may be thus found out.



Let *A B* repreſent a Cylinder with two perfect revolutions in it, unto which cylinder the perpendicular line *C D* is equall: the baſis *D E* being ſuppoſed to bee double unto the compaſſe or circumference of the cylinder. Now it is certain that the angle *C E D*, is the ſame with that by which the revolutions on the cylinder are framed, and that the line *E C*, in compariſon to the baſis *E D*, does ſhew the inclination of theſe revolutions unto the Horizon. The grounds and demonſtration of this are more fully ſet downe by *Guidus Vbaldus*, in his Mechanicks, and that

other Treatise *De Vectibus*, which he writ purposely for the explication of this instrument, where the subtilties of it are largely and excellently handled.

Now if this Screw which was before perpendicular, bee supposed to decline unto the Horizon by the angle *F B G*, as in this second figure;



then the inclination of the revolutions in it, will be increased by the angle *E DH*, though these revolutions will still remain in a kind of ascent, so that water cannot bee turned through them.

But

But now, if the Screw be placed so far declining, that the angle of its inclination *FBG*, be lesse then the angle *ECD*, in the triangle, as in this other Diagram under the former; then the revolutions of it will descend to the Horizon, as does the line *EC*, and in such a posture, if the Screw be turned round, water will ascend through its cavity. Whence it is easie to conceive the certain declination wherein any Screw must bee placed for its owne conveyance of water upwards. Any point betwixt *H* and *D*, being in descent, but yet the more the Screw declines downwards towards *D*, by so much the more water will be caried up by it.

If you would know the just quantity of water which every revolution does contain and carry, according to any inclination of the cylinder, this may be easily found by ascribing on it an *Ellipsis*, parallel to the Horizon; which *Ellipsis* will shew how much of the revolution is empty, and how much full.

See a further explication of this in Dædalus de Cochlea, l. 2 Propos. 5.

The

The true inclination of the Screw being found, together with the certain quantity of water which every *helix* does contain, it is further considerable, that the water by this instrument does ascend naturally of it self without any violence or labour, and that the heavinesse of it does lie chiefly upon the centers or axis of the cylinder, both its sides being of equall weight (saith *Rhodius*;) So that (it should seem) though we suppose each revolution to have an equall quantity of water, yet the Screw will remain with any part upwards (according as it shall be set) without turning it self either way. And therefore the least strength being added to either of its sides, should make it descend, according to that common maxime of *Archimedes*, any addition will make that which equiponderates with another, to tend downwards.

Ibid. l. 3. prop. 4.

De Aequipond. Suppos. 3.

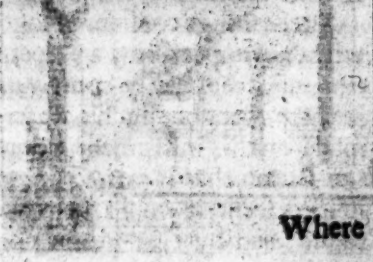
But now, because the weight of this instrument, and the water in it does depend wholly upon the axis, hence

hence is it (saith *Ubaldus*) that the grating and rubbing of these axes against the sockets wherein they are placed, will cause some ineptitude and resistency to that rotation of the cylinder, which would otherwise ensue upon the addition of the least weight to any one side; But (saith the same Authour) any power that is greater then this resistency which does arise from the axis, will serve for the turning of it round.

These things considered together, it wil hence appear, how a perpetual motion may seem easily contrivable. For if there were but such a water-wheel made on this instrument, upon which the stream that is carried up, may fall in its descent, it would turn the Screw round, and by that means convey as much water up, as is required to move it, so that the motion must needs be continuall, since the same weight which in its fall does turn the wheel, is by the turning of the wheel carried up again.

Or if the water falling upon one wheel

wheel would not be forcible enough for this effect, why then there might be two or three, or more, according as the length and elevation of the instrument will admit; By which means the weight of it may bee so multiplied in the fall, that it shall bee equivalent to twice or thrice that quantity of water which ascends. As may be more plainly discerned by this following Diagram.



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Where the figure *L M*, at the bottome does represent a wooden cylinder with helicall cavities cut in it, which at *A B*, is supposed to be covered ever with tin plates, and three water-wheels upon it *H I K*. The lower cistern which contains the water being *C D*. Now this cylinder being turned round, all the water which frō the cistern ascends through it, will fall into the vessell at *E*, and from that vessell being conveyed upon the water-wheel *H*, shall consequently give a circular motion to the whole Screw: Or if this alone should bee too weak for the turning of it, then the same water which fals from the wheel *H*, being received into the other vessell *F*, may from thence againe descend on the wheel *I*, by which means the force of it will be doubled. And if this be yet insufficient, then may the water which fals on the second wheel *I*, be received into the other vessell *G*, and from thence again descend on the third wheel at *K*: and so for as many

There is another like contrivance to this purpose in Pet. Bettin. *Apiar. 4. Progym. 1. Prop.* 10. but with much lesse advantage then 'tis here proposed.

many other wheeles, as the inſtrument is capable of. So that beſides the greater diſtance of theſe three ſtreams from the center or axis, by which they are made ſo much heavier, & beſides, that the fal of this outward water is forcible and violent, whereas the aſcent of that within is naturall; Beſides all this, there is thrice as much water to turn the Screw, as is carried up by it.

But on the other ſide, if all the water falling upon one wheel, would be able to turn it round, then half of it would ſerve with two wheels; and the reſt may be ſo diſpoſed of in the fall, as to ſerve unto ſome other uſefull delightfull ends.

When I firſt thought of this invention, I could ſcarce forbear with *Archimedes* to cry out εὕρηκα εὕρηκα; It ſeeming ſo infallible a way for the effecting of a perpetuall motion, that nothing could bee ſo much as probably objected againſt it: But upon triall and experience I finde it altogether inſufficient for any ſuch

purpoſe

purpoſe, and that for theſe two reaſons:

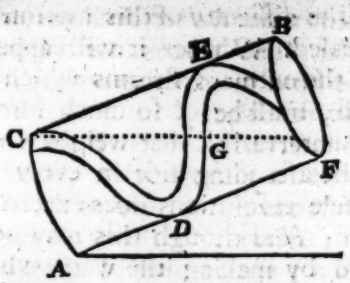
1. The water that aſcends will not make any conſiderable ſtream in the fall.

2. This ſtream (though multiplied) will not bee of force enough to turn about the Screw.

1. The water aſcends gently and by intermiſſions, but it fals continuately and with force; each of the three veſſels being ſuppoſed full at the firſt, that ſo the weight of the water in them might adde the greater ſtrength and ſwiftneſſe to the ſtreames that deſcend from them; Now this ſwiftneſſe of motion will cauſe ſo great a difference betwixt them, that one of theſe little ſtreams may ſpend more water in the fall, then a ſtream ſix times bigger in the aſcent, though wee ſhould ſuppoſe both of them to be continuate; How much more then, when as the aſcending water is vented by fits and intermiſſions, every circumvolution voiding onely ſo much as is con-

tained in one *Helix*? And in this particular, one that is not verſed in theſe kind of experiments, may bee eaſily deceived.

But ſecondly, though there were ſo great a diſproportion, yet notwithſtanding the force of theſe outward ſtreams, might well enough ſerve for the turning of the Screw, if it were ſo that both its ſides would equiponderate the water being in them (as *Vbaldus* hath affirmed.) But now upon farther examination, we ſhall find this aſſertion of his, to be utterly againſt both reaſon and experience. And herein does conſiſt the chief miſtake of this contrivance. For the aſcending ſide of the Screw is made by the water contained in it ſo much heavier then the deſcending ſide, that theſe outward ſtreams thus applied, will not be of force enough to make them equiponderate, much leſſe to move the whole. As may be more eaſily diſcerned by this figure.



Where *A B*, represents a Screw covered over, *C D E*, one *Helix* or revolution of it, *C D*, the ascending side, *E D* the descending side, the point *D* the middle. The Horizontall line *C F*, shewing how much of the *Helix* is filled with water, *viz.* of the ascending side, from *C* the beginning of the *Helix* to *D* the middle of it; and on the descending side, from *D* the middle, to the point *G*, where the Horizontall does cut the Helix. Now it is evident that this later part *D G*, is nothing neare so much, and consequently not so heavy as the other *D C*. And thus is it in all the other revolutions, which as they are either more or larger, so

will the difficulty of this motion bee increased. Whence it will appeare, that the outmard ſtreams which deſcend, muſt be of ſo much force as to countervail all that weight whereby the aſcending ſide in every one of theſe revolutions does exceed the other; And though this may be effected by making the water-wheels larger, yet then the motion will be ſo ſlow, that the Screw will not be able to ſupply the outward ſtreams.

There is another contrivance to this purpoſe mentioned by *Kircher de Magnete*, *l.2. p.4.* depending upon the heat of the ſun, and the force of winds, but it is liable to ſuch abundance of exceptions, that it is ſcarce worth the mentioning, and does by no means deſerve the confidence of any ingenuous artiſt.

Thus have I briefly explained the probabilities and defects of thoſe ſubtle contrivances, whereby the making of a perpetuall motion hath been attempted. I would be loath to diſcourage the enquiry of any ingenuous artificer.

artificer, by denying the possibility of effecting it with any of these Mechanicall helps; But yet (I conceive) if those principles which concern the slownesse of the power in comparison to the greatnesse of the weight, were rightly understood, and throughly considered, they would make this experiment to seem (if not altogether impossible, yet) much more difficult then otherwise perhaps it will appear. However, the inquiring after it, cannot but deserve our endeavours, as being one of the most noble amongst al these Mechanicall subtilties. And (as it is in the fable of him who dugge the Vineyard, for a hid treasure, though he did not finde the money, yet hee thereby made the ground more fruitfull, so) though we doe not attaine to the effecting of this particular, yet our searching after it may discover so many other excellent subtilties, as shall abundantly recompense the labour of our enquiry.

Treated of before, l. 1. c.

And then besides, it may be another encouragement to consider the

pleasure of such speculations, which doe ravish and sublime the thoughts with more cleare angelicall contentments. *Archimedes* was generally so taken up in the delight of these Mathematicall studies of this familiar *Siren*, (as *Plutarch* styles them) that he forgot both his meat and drink, and other necessities of nature; nay, that he neglected the saving of his life, when that rude soldier in the pride and hast of victory, would not give him leisure to finish his demonstration. What a ravishment was that, when having found out the way to measure *Hiero's* Crown, he leaped out of the Bath, and (as if he were suddenly possest) ran naked up and down crying εὕρηκα εὕρηκα! It is storied of *Thales* that in his joy and gratitude for one of these Mathematicall inventions, he went presently to the Temple, and there offered up a solemn sacrifice. And *Pythagoras* upon the like occasion is related to have sacrificed a hundred oxen. The justice of providence having

οἰκείας καὶ συνοίκου σειρῆνος. *Plutarch. Marcell. Ioan. Tzetzes, Chil. 2. Hist. 35. Valer. Maxim. l. 8. c. 7.*

ving ſo contrived it, that the pleaſure which there is in the ſucceſſe of ſuch inventions, ſhould be proportioned to the great difficulty and labour of their inquiry.

FINIS.